NEW YORK STATE
PUBLIC SERVICE COMMISSION

Case 15-E-0302 – Proceeding on Motion of the
Commission to Implement a Large-Scale Renewable
Program and Clean Energy Standard

COMMENTS OF INDEPENDENT
POWER PRODUCERS OF NEW YORK, INC.

Dated: August 16, 2023
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The Climate Leadership and Community Protection Act ("CLCPA" or "Climate Act") establishes a target of a zero-emission statewide electric system by 2040 (the “2040 Zero Emissions Target”). Recognizing the fact that existing renewable energy technologies alone are incapable of supporting electric system reliability assuming fossil fuel generation is removed to meet the 2040 Zero Emissions Target, on May 18, 2023, the New York State Public Service Commission (the “Commission”) issued an order in the above-captioned case initiating a process to identify the necessary complementary technologies that must be added to the system to support electric system reliability needs and the mechanism needed to facilitate their development. Pursuant to the notice soliciting comments in the May 18 Order and the notice extending the comment period, issued on June 28, 2023, Independent Power Producers of New York, Inc. ("IPPNY"), a not-for-profit trade association representing the independent power

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1 The 2040 Zero Emissions Target is codified in Section 66-p(2) of the New York Public Service Law ("PSL"). It provides, in relevant part: “. . . the commission shall establish a program to require that: (a) a minimum of seventy percent of the state wide electric generation secured by jurisdictional load serving entities to meet the electrical energy requirements of all end-use customers in New York state in two thousand thirty shall be generated by renewable energy systems; and (b) that by the year two thousand forty (collectively, the “targets”) the statewide electrical demand system will be zero emissions.”

2 Case 15-E-0302, Proceeding on Motion of the Commission to Implement a Large-Scale Renewable Program and a Clean Energy Standard, Order Initiating Process Regarding Zero Emissions Target (May 18, 2023) ("May 18 Order").

3 Case 15-E-0302, supra, Notice Extending Comment Period (June 28, 2023).
industry in New York State, hereby offers its comments in response to the Commission’s
invitation to parties to submit comments regarding resources that are capable of supporting the
reliability of a zero-emissions electric system and actions that should be taken to achieve the
2040 Zero Emissions Target.4

IPPNY member companies are involved in the development of electric generating
facilities, including renewable resources, the generation, sale, and marketing of electric power,
the development of natural gas facilities and the development of energy storage facilities in the
State of New York. IPPNY member companies produce a majority of New York’s electricity,
utilizing almost every generation technology available today, such as wind, solar, natural gas, oil,
run of river hydro, biomass, energy storage, waste-to-energy, and nuclear.

I. BACKGROUND

On August 18, 2021, IPPNY, New York State Building & Construction Trades Council
and New York State AFL-CIO (collectively “IPPNY/Unions”) petitioned5 the Commission in
this proceeding to establish a new competitive program or tier under the Clean Energy Standard
(“CES”) to encourage the development of zero emitting electric generating facilities that are not
renewable energy systems, as defined in the CLCPA pursuant to paragraph (b) of subdivision 1
of Section 66-p of the PSL.6 As IPPNY/Unions demonstrated in their Petition and as the
Commission recognized in its May 18 Order in response to the Petition, several studies
performed for the Commission and the New York Independent System Operator, Inc.
(“NYISO”) demonstrate that renewable generation cannot alone support electric system

4 IPPNY’s comments do not necessarily represent the position of its individual members.
5 Case 15-E-0302, supra, Petition of Independent Power Producers of New York, Inc., New York State Building &
Construction Trades Council and New York State AFL-CIO for the Establishment of a Zero Emissions Energy
6 See PSL § 66-p(1)(b).
reliability needs assuming fossil fuel generation is removed from the electric system to meet the
2040 Zero Emissions Target and that adding transmission is only a partial solution. As the
Commission stated, “[t]hese studies suggest that there is a gap between the capabilities of
existing renewable energy technology and expected future system reliability requirements”
which “could be bridged with zero emissions resources that have performance characteristics
similar to those of existing fossil fuel generators or that depart from that conventional profile.”

Consistent with the results of NYISO studies conducted to date, IPPNY and the
Commission established the need for significant levels, approximately 17–45 gigawatts (“GW”),
of dispatchable emission-free resources (“DEFRs”) to meet system reliability needs by 2040. For
example, in its Outlook, the NYISO confirmed that DEFRs that provide sustained on-
demand power and system stability will be critical to replace the electrical attributes that fossil
fueled generation has been providing to achieve a reliable, emission-free grid. The NYISO’s

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7 May 18 Order at 11.
8 May 18 Order at 2, 10.
102 (projecting that zero emissions could be achieved by 2040 with 17 GW to 23 GW of thermal backstop
generation fueled with landfill gas, biogas, or other renewable natural gas), https://www.nyserda.ny.gov/-
/Projects/Nyserda/Files/Publications/NY-Power-Grid/full-report-NY-power-grid.pdf; 2021–2040 System &
Resource Outlook, NYISO (Sept. 22, 2022) (“Outlook”), at 9–11 (concluding 27 GW to 45 GW of DEFRs will
be needed to meet reliability needs by 2040”), https://www.nyiso.com/documents/20142/33384099/2021-2040-
Outlook-Report.pdf; Paul J. Hibbard et al., Climate Change Impact Phase II, An Assessment of Climate Change
Climate Study”), at 83–84 (concluding that removal of all the existing fossil-fueled generating resources by 2040 in
compliance with the 2040 Zero Emissions Target will require greater than 30 GW of installed capacity of new
flexible and dispatchable resources to provide the necessary reliability services that have historically been provided
by fossil-fueled generating resources),
%20Study%20Phase%202.pdf;89647ae3-6005-70f5-03c0-d4ed33623ce4. The NYISO’s Outlook defined DEFRs as
“a proxy generator type assumed for generation expansion in the Policy Case to represent a yet unavailable future
technology that would be dispatchable and produces emissions-free energy (e.g., hydrogen, RNG, nuclear, other
long-term season storage, etc.).” Outlook at 48. The New York State Climate Action Council’s Scoping Plan
indicated that its “analysis and current studies show that the 100x40 goal requires 15 GW to 45 GW of electricity
from zero-emission, dispatchable resources in 2040 to meet demand and maintain reliability.” New York State
Climate Action Council Scoping Plan, New York State Climate Action Council (Dec. 2022) (“Scoping Plan”), at 13,

10 Outlook at 60.
analysis indicated that a majority of DEFRs will be needed in New York City and Long Island, due to their locational capacity requirements, as early as 2035 and continuing through 2040. In one of the scenarios the NYISO studied, the amount of DEFR capacity required in these zones is more than double the fossil generation capacity today.

In their Petition, IPPNY/Unions highlighted the CLCPA’s 2040 Zero Emissions Target and pointed to the fact that the CLCPA also requires the Commission to conduct a biennial review determining: “(a) progress in meeting the overall targets for deployment of renewable energy systems and zero emission sources,” thus indicating the Legislature’s clear intention that zero emissions sources are a category of resources distinct from renewable energy systems. While the Commission noted that it had already ruled that “renewable energy systems” under PSL §66-p(1)(a) and existing nuclear generation are “zero emissions” for purposes of meeting the 2040 Zero Emissions Target, it agreed with IPPNY/Unions that the CLCPA does not define “zero emissions, leaving it to the Commission to define the term.” IPPNY/Unions cautioned that the Commission’s silence to date on this matter is creating uncertainty in the electricity market and investment community, thereby potentially delaying, unnecessarily, the development of resources that are both zero emitting and capable of meeting electric system needs that cannot be met fully by renewable energy systems.

11 Outlook at 51.
12 Id.
13 PSL § 66-p(3).
14 The Legislature made clear that a minimum of 70% of generation to meet New York’s electricity requirements must be generated by renewable energy systems. See PSL § 66-p(2). If the Legislature intended that renewable energy system must generate 100% of the State’s electricity requirements by 2040, it would have so stated instead of requiring that “the statewide electrical demand system will be zero emissions” by 2040. Thus, the Legislature intended that up to 30% of the State’s electricity requirements could be served by non-renewable generation.
15 May 18 Order at 12.
16 Petition at 6–7.
In response to the Petition and based on the demonstrated need for DEFRs in the studies referenced in its May 18 Order, the Commission concluded that it must explore technologies that can support reliability as and after fossil fuel resources leave the system. The Commission initiated a process “to determine appropriate next steps” to address this issue, “including consideration of whether it is appropriate for the Commission to allocate ratepayer funds to incentivize the deployment of zero-emission technologies.” The Commission requested comments on, and posed a series of questions related to, how “zero emissions” should be defined and whether specific technologies including new nuclear, biofuels, hydrogen, and carbon capture and sequestration should be “candidates for a ‘zero emission’ CES Tier.”

II. THE COMMISSION SHOULD ISSUE AN ORDER EXPEDITIOUSLY IDENTIFYING ZERO EMISSIONS TECHNOLOGIES AND SPECIFYING THEY CAN BE A SEPARATE CATEGORY FROM RENEWABLE RESOURCES

IPPNY appreciates the Commission’s initiation of a process to identify zero emissions technologies and the actions needed to maintain reliability in the transition to a zero emitting electric system. As discussed in greater detail below and in the attached supporting Affidavit of David W. Cohn, Vice President at Sargent & Lundy, LLC, attached hereto as Exhibit 1, in response to the questions posed in the May 18 Order, the Commission should rule that zero emissions sources are systems, other than renewable energy systems, that can individually, or

\[17\] May 18 Order at 11–12.
\[18\] Id. at 12.
\[19\] Id. at 13.
\[20\] While IPPNY agrees with the Commission that renewable resources are zero emissions sources, the Commission’s focus in this process at this time should be on non-renewable zero emissions sources because currently available renewable resources are incapable of meeting the system reliability needs the Commission seeks to address in this case and the Commission has already adopted programs to support and encourage the deployment of renewable resources. If renewable resources or any other resource not specifically addressed in this process are developed that can provide the reliability services of a DEFR, the Commission can evaluate such resources on a case-by-case basis and include such resources in the list of resources that are eligible for the Commission’s programs providing financial support to DEFRs.
in combination, deliver net zero GHG equivalent electricity, and the technologies that qualify as zero emissions sources for purposes of meeting the 2040 Zero Emissions Target include: existing and advanced nuclear, long-duration storage, green and pink hydrogen and derivatives thereof, renewable natural gas (“RNG”) and derivatives thereof, carbon capture, utilization, and storage (“CCUS”) (including direct air capture (“DAC”)), distributed energy resources (“DERs”) (including virtual power plants (“VPPs”) and fuel cells), and demand response resources. This list of technologies is not intended to be exclusive of other technologies, as they emerge, that could help meet the 2040 Zero Emissions Target and fill the gap between the capabilities of existing renewable energy technology and expected future system reliability requirements.

Some parties may argue that the combination of wind, solar and battery storage should be the sole means to satisfying the 2040 Zero Emissions Target because a technological breakthrough will arrive in time to make long duration storage feasible to fill the gap. As noted above, the gap is monumental, 17–45 GW. The capacity of DEFRs needed is greater than the capacity of existing fossil fueled generation in the State and much greater than the 12.9 GW of generation of all types that was added to the system over the last 20 years.\(^{21}\) To deploy such quantities of resources, on top of the renewable energy systems and transmission development already underway, in the next 16 years will require an unprecedented level of development effort that will need to begin immediately. The Commission risks making the perfect the enemy of the good if it rejects technologies perceived by some parties as not 100% zero emitting but that could begin significantly reducing GHG emissions now in hopes that a technological breakthrough in

\(^{21}\) Outlook at 59.
battery storage will arrive in time to fill the gap.\textsuperscript{22} Importantly, the Legislature recognized the diminishing returns of reaching 100\% zero emissions by permitting “\textit{a de minimis} threshold of greenhouse gas emissions below which emission reduction requirements will not apply.”\textsuperscript{23}

If the gap cannot be filled with DEFRs by 2040, the Commission will have no choice but to exercise its authority under PSL §66-p(2) to modify the 2040 Zero Emissions Target to ensure an adequate quantity of existing and potentially new fossil fueled generation can remain in, or enter, service to maintain the reliability of the electric system beyond 2040.\textsuperscript{24} Therefore, the Commission should cast a broad net to consider and qualify as many technologies as possible that have the capability to fill the gap and reduce GHG emissions to, or as near as possible to, zero. The Commission also should work with the New York State Department of Environmental Conservation (“DEC”) to determine the status of existing or new emission control technologies to address emissions that are not determined to be \textit{de minimis} for technologies determined to be eligible to meet the 2040 Zero Emissions Target.

As the Commission recognized in its May 18 Order, the Legislature granted the Commission express authority to “consider and where applicable formulate the program[s] to address impacts of the program[s] on safe and adequate electric service in the state under reasonably foreseeable conditions” and “modify the obligations of jurisdictional load serving entities and/or the targets upon consideration of” impacts to safe and adequate electric service.\textsuperscript{25}

\textsuperscript{22} The Commission should also consider that long duration storage paired solely with intermittent renewables would require an extensive overbuild of solar and wind facilities to supply such storage through seasonal and sporadic wind and solar lulls.

\textsuperscript{23} New York Environmental Conservation Law (“ECL”) § 75-0103(14)(c).

\textsuperscript{24} One of the consequences of failing to act on defining DEFRs will also be an increased reliance on imports from other states that do not have as stringent GHG requirements as New York does, which will simply shift emissions across the border.

\textsuperscript{25} May 18 Order at 9 (quoting PSL § 66-p(2)).
The CLCPA also provides that “the Commission may temporarily suspend or modify” the program if it finds “that the program impedes the provision of safe and adequate electric service; the program is likely to impair existing obligations and agreements; and/or that there is a significant increase in arrears or service disconnections that the commission determines is related to the program.” Thus, the Legislature’s intent is clear that maintaining the reliability of the electric system is paramount and cannot be subordinated to meeting the 2040 Zero Emissions Target.

As noted above, the CLCPA does not define “zero emissions.” Given the other definitions contained therein, this fact leaves the term to be defined by the Commission. Based on the CLCPA’s explicit grant of authority to the Commission to fashion the program in a manner that ensures it will not adversely impact reliability of the electric system and the Commission’s authority and obligation to ensure safe and adequate electric service generally under PSL § 65, the Commission has ample authority and discretion to define zero emissions and establish the methods and resources to achieve the 2040 Zero Emissions Target in a manner that best ensures electric system reliability will be maintained during, and following, the transition to a zero emissions electric system. Consistent with the Climate Act’s establishment of a goal of net zero emissions across all sectors of the economy by 2050, the Commission should rule that GHG emissions are measured on a net basis rather than a gross basis for purposes of meeting the 2040 Zero Emissions Target. The Commission should also rule that a technology that produces emissions that are de minimis in the context of the total emissions reduced by the

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26 PSL § 66-p(4).
27 ECL § 75-0109. The Scoping Plan stated that it “is designed to act as a plan that the State should follow to meet the requirements of the statewide greenhouse gas (GHG) emission limits and achieve statewide net zero emissions pursuant to the [CLCPA].” Scoping Plan at 51.
technology qualifies as a zero emissions resource for purposes of meeting the 2040 Zero
Emissions Target. Defining zero emissions in this manner will facilitate the inclusion of the
broadest possible set of technologies that have the capability to fill the gap and reduce GHG
emissions from the electricity sector to, or to near, zero.\textsuperscript{28} It would qualify a potential resource,
such as a generator using CCUS, as a zero emissions source if it reduces GHG emissions by 90%
to 99%, or, in the case of RNG, if it results in a net reduction of GHG emissions to zero.

The Commission posits in its May 18 Order that its discretion to interpret the CLCPA
may be constrained by the CLCPA’s mandate to the DEC to adopt regulations to implement the
CLCPA’s emissions reduction targets of 60% of 1990 emissions by 2030 (“60 by 30 Target”)
and 15% of 1990 emissions by 2050 (“15 by 50 Target” and with the 60 by 30 Target, the “GHG
Targets”).\textsuperscript{29} However, it is the DEC’s actions that are constrained by the Commission’s
obligations under the CLPCA to ensure safe and adequate electric service.

The Legislature specifically granted the Commission the authority to fashion its program
to achieve the 2040 Zero Emissions Target and to modify such target to ensure safe and adequate
electric service. The Legislature directed DEC to adopt regulations to achieve the GHG Targets
but did not specifically require DEC to fashion its regulations or modify the GHG Targets to
ensure safe and adequate electric service. This makes sense as the Commission is the State
agency that has the expertise and capability to protect public health and safety by taking

\textsuperscript{28} The New York Court of Appeals held that, in the absence of explicit statutory authorization, the Commission may
assert regulatory power if a realistic appraisal of the particular situation demonstrates that its “administrative action
reasonably promotes or transgresses the pronounced legislative judgment.” In re Consol. Edison Co. of N.Y. v. Pub.

\textsuperscript{29} May 18 Order at 13 (quoting ECL § 75-0107(1)).
regulatory action to maintain electric system reliability. The Legislature could not have intended that DEC’s regulations implementing the GHG Targets could undercut the Commission’s obligation to implement the CLCPA in a manner that ensures safe and adequate service. Thus, reading the various parts of the CLCPA related to the Commission and DEC harmoniously, DEC should accede to the Commission’s definition of zero emissions as it relates to electric system resources and the Commission’s designation of zero emissions resources and forego adopting regulations implementing the GHG Targets that interfere, or are inconsistent, with the Commission’s determinations on these matters. The Commission and DEC should work closely together and in consultation with the NYISO to establish rules implementing the CLCPA to avoid the adoption of rules that may inadvertently jeopardize electric system reliability.

The Commission should act as quickly as possible to designate technologies that qualify as zero emissions so that developers and investors can begin considering them as replacements to fossil fueled generating facilities to meet reliability needs. The NYISO’s recently issued second quarter Short-Term Assessment of Reliability (“STAR”) identified a deficit in reliability margins

30 The Climate Action Council’s Scoping Plan accurately notes, “[w]hile transitioning away from fossil fuel use, maintaining reliable access to power, whether through centralized or distributed energy sources, is crucial for maintaining good public health in our energy-dependent society.” Scoping Plan at 105.


32 The courts must “harmonize the various provisions of related statutes and . . . construe them in a way that renders them internally compatible.” Matter of Aaron J., 80 N.Y.2d 402, 407 (1992); see N.Y. Stat. Law §§ 97, 98 (McKinney 2023). The Commission noted in its May 18 Order that DEC’s consideration of the combustion of biomass as contributing to gross emissions under the CLCPA “is relevant to, though, not necessarily determinative of, whether the use of biomass as fuel for power plants can be considered zero-emissions for the purpose of compliance with PSL §66-p(2), or net-zero for purposes of the CLCPA’s separate net-zero emissions target.” May 18 Order at 14. DEC’s regulations implementing the CLCPA should accommodate, not undercut, the Commission’s designation of RNG and derivatives thereof to fuel DEFRs as zero emissions because they are necessary to help maintain system reliability.
as large as 446 megawatts ("MW") in New York City beginning in the summer of 2025.\(^{33}\) The deficit is driven primarily by the combination of a forecasted increase in peak demand and the expected unavailability of certain generators due to DEC’s Peaker Rule.\(^{34}\) The NYISO is currently soliciting market solutions to meet the reliability need.\(^{35}\) The NYISO stated that, if proposed solutions are unable to meet the identified reliability need, the NYISO may need to permit generators that are subject to the Peaker Rule to remain in operation for some or all of the two two-year periods expressly provided to the NYISO by the Peaker Rule until a permanent solution is in place.\(^{36}\) Due to the risk of being saddled with stranded investment costs in expensive modifications, developers are unlikely to propose a DEFR technology to address this identified reliability need and other reliability needs that are likely to arise in the future until the Commission approves technologies as zero emissions sources. The Commission’s approval is necessary to provide the certainty that developers and investors need that projects will be compliant with the 2040 Zero Emissions Target and will have a sufficient operating time horizon, which dictates the amortization period for recovery of a project’s capital costs.

The Commission should also rule quickly to reduce regulatory uncertainty regarding the United States Environmental Protection Agency’s (“EPA”) proposed rule imposing new source performance standards and emission guidelines under Section 111 of the Clean Air Act that


\(^{34}\) Id. at 4. In 2019, DEC adopted a regulation to limit nitrogen oxides ("NOx") emissions from simple-cycle combustion turbines, referred to as the “Peaker Rule,” which has caused over 1,000 MW of peaking facilities to deactivate or limit their operation. Id. at 11; see also ECL § 227.3.1 et seq.


\(^{36}\) Id. The Peaker Rule permits generators to remain in operation temporarily if the NYISO determines they are needed to maintain reliability. July STAR at 11.
reflect the application of the best system of emission reduction for new and existing fossil-fired generating facilities. Under the proposed rule, certain new and existing fossil fueled generating facilities would be required to reduce GHG emissions by either installing carbon capture and sequestration/storage ("CCS") or blending green hydrogen with natural gas. Specifically, existing combustion turbines over 300 MW with capacity factors greater than 50 percent would be required to either use CCS with a 90% capture rate by 2035 or co-fire 30% (by volume) low-GHG hydrogen by 2032 and 96% (by volume) by 2038. New and reconstructed intermediate load combustion turbines ("CTs") would likewise be required to co-fire 30% low-GHG hydrogen by 2032 and base load CTs must either install CCS or co-fire with low-GHG hydrogen. If they install CCS, they would be required to do so by 2035 and achieve a 90% GHG reduction. If they co-fire with low-GHG hydrogen, they would be required to co-fire 30% (by volume) by 2032 and 96% by 2038. The EPA stated that it intends to undertake a separate rulemaking to address the remainder of the existing fossil fuel fired combustion fleet, as expeditiously as practicable.

As the various studies demonstrate, much of the existing fleet of dispatchable fossil generation in New York will likely need to continue operating to support reliability until modified or replaced with zero emissions technology that complies with the 2040 Zero

38 Id. at 33245–46.
39 Id. at 33244.
40 Id.
41 Id.
42 Id. at 33362.
Emissions Target. If the EPA Proposed GHG Rule is adopted, generator owners with affected CTs in New York will need to act quickly in making the necessary capital investments to modify their facilities in time to begin co-firing low-GHG hydrogen by 2032 or deploying CCS by 2035. To avoid being saddled with stranded costs that would be unrecoverable if modified CTs are required to deactivate by 2040, generator owners are unlikely to move forward with these investments unless and until the Commission rules that the CCS and combusting low-GHG hydrogen technologies described in the proposed rule, at a minimum, are zero emissions technologies for purposes of the 2040 Zero Emissions Target or the Commission modifies the 2040 Zero Emissions Target to allow facilities equipped in this manner to operate beyond 2039.

The Commission should establish a new tier under the CES to incent the deployment of the zero emission resources that the Commission identifies in this proceeding to help meet the 2040 Zero Emissions Target. The New York State Energy Research and Development Authority (“NYSERDA”) should begin conducting annual competitive solicitations as soon as possible to procure zero emissions credits (“ZECs”) from eligible zero emissions resources. To jumpstart the significant investment that will be needed to develop the necessary infrastructure to support the combustion of green hydrogen, the Commission should require NYSERDA to solicit resources that can soon begin co-firing small volumes of green or pink hydrogen with natural gas as early as 2032 and no later than 2038, with a phase-in to 100% green or pink hydrogen by 2040. The solicitations will provide valuable information to the Commission regarding the technical and economic feasibility of these technologies to support the reliability of the electric system through the clean energy transition and will allow these technologies to become available in time to meet the 2040 Zero Emissions Target.
III. RESPONSES TO QUESTIONS POSED IN THE MAY 18 ORDER.

1. How should the term “zero emissions,” as used under PSL §66-p(2)(b), be defined?

The term “zero emissions” should be defined as broadly as possible to allow for the consideration of any technology that can assist the State in achieving the ambitious targets set in the CLCPA. As discussed in Point II, above, the Commission should rule that “zero emissions” should be defined as an electrical demand system that delivers net zero GHG emission equivalent electricity. The Commission should also rule that a technology that produces emissions that are de minimis in the context of the total emissions reduced by the technology qualifies as a zero emissions resource for purposes of meeting the 2040 Zero Emissions Target.

“Net zero” is the balance between GHG that is produced and the amount that is removed. It means “cutting [GHG] emissions to as close to zero as possible, with any remaining emissions re-absorbed from the atmosphere, by oceans and forests for instance.”43 Zero emissions sources can therefore be defined as systems, other than renewable energy systems, that can individually, or in combination, deliver net zero GHG equivalent electricity. The Commission should acknowledge, as other states have, that reducing more potent methane gas with a percentage of carbon dioxide into the atmosphere qualifies as net zero.

Defining the term “zero emissions” to include systems that generate electricity with net-zero GHG emissions would also bring the State into alignment with the renewable energy portfolio standards and GHG emission reduction objectives of many other states in the nation. Several state legislatures have delegated the authority to determine whether certain technologies would qualify under their respective renewable standards to their state public utility

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commissions. For example, Colorado’s Renewable Energy Standard (“RES”) includes resources “using coal mine methane and synthetic gas produced by pyrolysis of waste materials” as eligible energy resources to meet its standards “if the commission determines that the electricity generated by those resources is greenhouse gas neutral.” 44 “Greenhouse gas neutral” means that:

the greenhouse gases emitted into the atmosphere as a result of the process of converting the fuel source to electricity do not exceed the greenhouse gases that would have been emitted into the atmosphere over the next five years, beginning with the commencement of the process or initial date of operation of the facility, if the fuel source had not been converted to electricity, where greenhouse gases are measured in terms of carbon dioxide equivalent. 45

The Colorado Public Utility Commission has determined that facilities, such as the Elk Creek 3 MW coal mine methane plant, is a GHG neutral eligible energy resource under its RES. 46

Other states have expressly included net-zero emissions resources as eligible resources to meet their RES targets. Connecticut defines a “Class I Energy Source” as energy derived from, inter alia, fuel cells, landfill methane gas, anaerobic digestion or other biogas derived from biological sources, and thermal electric direct energy conversion from a certified Class I renewable energy source. 47 Hawaii’s definition of “renewable energy” includes biogas, biomass, biofuels, and hydrogen produced from renewable energy sources. 48 In addition, California, 49

46 Proceeding No. 18A-0444E, Elk Creek 3 MW Power Project, Recommended Decision (Dec. 6, 2018) at ¶ 21.
Illinois,\textsuperscript{50} Minnesota,\textsuperscript{51} North Carolina,\textsuperscript{52} Oregon,\textsuperscript{53} Virginia,\textsuperscript{54} and Washington\textsuperscript{55} enacted definitions of renewable or zero-emissions resources that include biofuel and/or hydrogen resources. New Mexico defines a “zero carbon resource” as a resource that “emits no carbon dioxide into the atmosphere, or that reduces methane emitted into the atmosphere in an amount equal to no less than one-tenth of the tons of carbon dioxide emitted into the atmosphere, as a result of electricity production.”\textsuperscript{56}

Accordingly, through this proceeding, the Commission should identify technologies that can complement renewable resources and provide the needed generation capacity and DEFRs, including those with \textit{de minimis} emissions, and provide incentives to ensure such technologies are built in a timely manner to meet the 2040 Zero Emissions Target.

2. \textbf{Should the term “zero emissions” be construed to include some or all of the following types of resources, such as advanced nuclear (Gen III+ or Gen IV), long-duration storage, green hydrogen, renewable natural gas, carbon capture and sequestration, virtual power plants, distributed energy resources, or demand response resources? What other resource types should be included?}

As discussed below and in greater detail in the attached Affidavit of David W. Cohn, the Commission should rule that technologies that qualify as zero emissions sources for purposes of meeting the 2040 Zero Emissions Target include: existing and advanced nuclear (discussed in response to Question 3), long-duration storage (discussed in response to Question 6), green and pink hydrogen and derivatives thereof, RNG and derivatives thereof, CCUS including DAC,

\begin{itemize}
  \item \textsuperscript{50} 20 Ill. Comp. Stat. 3855/1-10.
  \item \textsuperscript{51} Minn. Stat. § 216B.1691.
  \item \textsuperscript{52} N.C. Gen. Stat. § 62-133.8.
  \item \textsuperscript{53} Or. Rev. Stat. § 469A.400(7).
  \item \textsuperscript{54} Va. Code Ann. § 56-576.
  \item \textsuperscript{55} Wash. Rev. Code § 19.405.020(28)(a).
\end{itemize}
DERs including VPPs and fuel cells (discussed in response to Questions 4 and 6, respectively), and demand response resources.

The Commission should also address the role transmission can play in helping to meet the 2040 Zero Emissions Target. In its May 18 Order, the Commission stated that downstate and New York City, in particular, will have a greater need for DEFRs.\textsuperscript{57} For a variety of reasons, it may not be feasible or economic to site certain DEFRs in Zone J, like nuclear. However, it may be feasible and economic to site these DEFRs upstate and transmit their power to Zone J over controllable transmission lines, which would provide the same reliability benefit as if the facilities were physically located in Zone J. Thus, in any program the Commission adopts to incent the deployment of DEFRs, it should consider proposals paired with controllable transmission lines.

\textbf{Green and Pink Hydrogen and Derivatives Thereof}

There are two methods of hydrogen energy production of note here: (1) green hydrogen is produced by electrolysis using electricity produced without the emission of GHGs, including renewable power and low-carbon power resources; and (2) pink hydrogen is produced by electrolysis powered by nuclear energy.\textsuperscript{58} GHGs are not formed when elemental hydrogen is combusted because the process does not involve carbon combustion.\textsuperscript{59}

\begin{footnotesize}
\begin{itemize}
\item May 18 Order at 10.
\item Aff. at ¶ 9. In the EPA Proposed GHG Rule, which, as discussed above, would require certain existing combustion turbines to either deploy CCS or co-fire low-GHG hydrogen, EPA proposed to define low-GHG hydrogen as hydrogen that is produced with overall carbon emissions of less than 0.45 kg CO\textsubscript{2}e/kgH\textsubscript{2} from well-to-gate. EPA Proposed GHG Rule at 33304. EPA stated that electrolytic hydrogen produced using zero-carbon emitting energy sources is the most likely form of hydrogen anticipated to meet this proposed definition. \textit{Id.} at 33309.
\item Aff. at ¶ 9.
\end{itemize}
\end{footnotesize}
hydrogen can be used as a dispatchable source to maintain electric system reliability just as natural gas generators provide dispatchable reliability service today.

The New York State Climate Action Council’s Scoping Plan noted that green and pink hydrogen technologies have seen notable advancements and offer new opportunities to address difficult to electrify sectors. The proposal for a Northeast Regional Clean Hydrogen Hub submitted to the United States Department of Energy (“DOE”) by New York, New Jersey, Maine, Rhode Island, Connecticut, Vermont, and Massachusetts included more than one dozen advanced clean electrolytic hydrogen production, consumption, and infrastructure projects, which demonstrates the State’s growing investment in these technologies. In addition, the State recently announced a $10 million initiative to advance clean hydrogen research, development, and demonstration projects aimed at addressing the challenges of hard-to-electrify sectors. The NY Renews Policy Committee supported green hydrogen, stating that: “If produced by carbon-free means and used for limited but essential energy purposes, hydrogen can be valuable in the energy mix of a decarbonizing economy.”

In the EPA Proposed GHG Rule, EPA stated that CTs currently being produced are capable of co-firing with low-GHG hydrogen and that retrofits have been developed to allow existing CTs to combust up to 100% hydrogen. Existing gas turbines can be upgraded with a combustor and fuel nozzles configured for operation on hydrogen. NOx emissions can be

60 Scoping Plan at 78.
64 EPA Proposed GHG Rule at 33363.
65 Aff. at ¶ 21.
mitigated through pre- or post-control technology such as water injection or selective catalytic reduction ("SCR"). Designating green and pink hydrogen as a zero emission source will allow New York to leverage the significant funding and other incentives Congress has provided to encourage their deployment.

As noted above, the EPA proposed that existing combined cycle CTs that operate at capacity factors of greater than 50% and that are greater than 300 MW will be required to co-fire 30% low-GHG hydrogen by 2032 and 96% by 2038. The EPA explained that “[c]o-firing hydrogen at these levels is adequately demonstrated, as indicated by announced plans of manufacturers and generators to undertake retrofit projects for hydrogen co-firing. These plans also indicate that the costs of retrofitting are reasonable.”

The EPA stated that it expects that as technology advances, growing demand for low-GHG hydrogen, and the hydrogen production tax credits available under the Inflation Reduction Act, Internal Revenue Code § 45V(b)(2), combined with the $8 billion for regional hydrogen hubs and $1.5 billion for electrolyzer advancement provided by the Infrastructure Investment and Jobs Act, should accelerate the production of low-GHG hydrogen to provide the quantities needed for affected CTs to co-fire 96% (by volume) low-GHG hydrogen by 2038. EPA further stated that “[s]uitable volumes of low-GHG hydrogen are expected to be produced by the 2032 and 2038 timeframes to satisfy the demand driven by this proposed rule.”

To provide hydrogen to electric generators, a robust hydrogen storage and transportation infrastructure will need to be developed to transport it from the point of production to the point

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66 Aff. at ¶ 21.
67 EPA Proposed GHG Rule at 33363.
68 EPA Proposed GHG Rule at 33373.
69 EPA Proposed GHG Rule at 33364.
of use.\textsuperscript{70} As Mr. Cohn states, “[c]onveyance of hydrogen is viable, however widespread distribution presents technical and commercial challenges and will require costs to be incurred to retrofit facilities.”\textsuperscript{71} Globally, hydrogen has been transported by pipeline since 1938; there are currently about 1,600 miles of operational hydrogen pipelines in the United States, 1,200 miles in Europe, and 125 miles in South Korea.\textsuperscript{72} Some hydrogen pipelines are operating in New York State.\textsuperscript{73} Many studies and demonstrations of hydrogen blending in existing gas transmission lines have taken place in Europe, and the United States has successfully commissioned several hydrogen blending projects. For example, since 1970, Hawai’i Gas, the only franchised gas utility in that state, has blended 12% to 15% of hydrogen with natural gas into its network.\textsuperscript{74}

The existing natural gas system can transport hydrogen blended up to about 20% with natural gas without significant change.\textsuperscript{75} However, to establish a blend greater than 20% hydrogen, existing natural gas pipelines will need to be repurposed to meet various technical challenges that may arise based on the type of pipeline and the operational characteristics of the pipeline.\textsuperscript{76}

Electrolytic hydrogen can be generated using nuclear power or intermittent renewable energy and can then be stored on-site for dispatchable generation when needed, provided that

\textsuperscript{70} Aff. at ¶ 9; see also Hydrogen Delivery, DOE Office of Energy Efficiency and Renewable Energy, \url{https://www.hydrogen.energy.gov/delivery.html} (last visited Aug. 15, 2023).

\textsuperscript{71} Aff. at ¶ 10.

\textsuperscript{72} Aff. at ¶ 10.


\textsuperscript{75} Aff. at ¶ 10.

\textsuperscript{76} Aff. at ¶ 10.
geologic conditions at the site are favorable. Constellation Energy Corp. (“Constellation”) has deployed an electrolysis system at Nine Mile Point Nuclear Station, in Oswego, New York, to generate hydrogen. Constellation received funding from the DOE and NYSERDA to construct the electrolyzer system and a hydrogen fuel cell, which is scheduled to provide long-duration storage power to the grid in 2025. This concept is also planned as part of the Advanced Clean Energy Storage project in Utah, where solution mined salt caverns will store up to 300 gigawatt hours (“GWh”) of energy. In addition to on-site storage, a recent study demonstrated that existing underground gas storage can store hydrogen-methane blends, which would sufficiently buffer the hydrogen demand projected for 2050.

As Mr. Cohn notes, generation of electricity through the combustion of hydrogen is commercially available today as CTs have combusted fuel with various amounts of hydrogen for decades. In fact, within the coming years, CTs that have the capability to combust 100% hydrogen could become a fleet-wide asset, as nearly all major original equipment manufacturers’ combustion turbines already have some capability to meet this goal with their current equipment.

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77 Aff. at ¶ 15.
81 Aff. at ¶ 19.
82 Aff. at ¶ 19.
Due to the high temperatures of the process of combusting hydrogen, nitrogen in the air reacts with oxygen to form NO$_x$. Some parties have argued that green hydrogen combustion should not be deemed a zero emission technology because it produces NO$_x$ emissions, which they claim is a co-pollutant that will harm disadvantaged communities, in contravention of the requirement in CLCPA § 7(3) that DEC (and all other New York agencies) “prioritize reductions of GHG emissions and co-pollutants in . . . disadvantaged communities as identified pursuant to such subdivision 5 of section 75-0101 of the environmental conservation law.” The Commission should reject such arguments. First, NO$_x$ is not defined as a co-pollutant under the CLCPA. Second, NO$_x$ has been regulated to reduce emissions below thresholds established by federal, state, and local regulatory agencies for several decades. To mitigate potential impacts, new and existing resources can be required to determine the best available control technology (“BACT”) to control these emissions. For NO$_x$, BACT commonly includes dry low emissions combustors, combustion dilution, and post-combustion mitigation such as SCR, all of which are long-established and effective tools that can be used in power plants combusting hydrogen.

83 Aff. at ¶ 22.
84 2019 N.Y. Sess. Laws ch. 106 § 7(3).
85 Co-pollutants are defined as “hazardous air pollutants produced by greenhouse gas emissions sources.” ECL § 75-0101(3). NO$_x$ is not a listed hazardous air pollutant. Instead, NO$_x$ is a criteria pollutant (Air Quality Monitoring, DEC, https://www.dec.ny.gov/chemical/8406.html (last visited Aug. 15, 2023) and is already regulated by the DEC’s existing programs—most notably through programs such as the DEC’s Peaker Rule. See Initial List of Hazardous Air Pollutants with Modifications, EPA (last updated Jan. 5, 2022), https://www.epa.gov/haps/initial-list-hazardous-air-pollutants-modifications. Notably, the DEC’s Air Toxics Program already includes requirements for hazardous air pollutants. See Air Toxics Program, DEC, https://www.dec.ny.gov/chemical/8568.html#Contaminants (last visited Aug. 15, 2023).
86 Aff. at ¶ 21.
87 Aff. at ¶ 21.
88 Aff. at ¶ 22.
In the EPA Proposed GHG Rule, the EPA stated that dry low NO\textsubscript{x} (“DLN”) combustion is the most used NO\textsubscript{x} combustion control for base load combined cycle turbines.\textsuperscript{89} While the EPA stated that the ability to reduce NO\textsubscript{x} with DLN combustors is currently more limited, all major CT manufacturers have developed DLN combustors for electric generators that can co-fire hydrogen.\textsuperscript{90} The EPA stated “moreover, the major combustion turbine manufacturers are designing combustion turbines that will be capable of combusting 100 percent hydrogen by approximately 2030, with DLN designs that assure acceptable levels of NO\textsubscript{x} emissions.”\textsuperscript{91}

Ammonia can serve as a hydrogen and energy carrier. A significant benefit of this technology is that, because about 20 million tons of ammonia are transported by sea each year, the necessary ships, ports, storage, and infrastructure are already in place.\textsuperscript{92} Compared to liquid hydrogen, ammonia requires less energy to liquify and transport and has a higher volumetric energy density. Electrolytic hydrogen and nitrogen produced from an air separation unit can be synthesized to produce green ammonia, all of which is powered from electricity produced without emitting GHGs.\textsuperscript{93} After the green ammonia is shipped, it can be converted back into green hydrogen and nitrogen. The direct use of ammonia has been successfully demonstrated in micro gas turbines (50 kilowatts). Mitsubishi Power, Ltd. announced plans to commercialize a

\textsuperscript{89} EPA Proposed GHG Rule at 33364.
\textsuperscript{90} Id.
\textsuperscript{91} Id.
\textsuperscript{93} Aff. at ¶ 27.
40 MW gas turbine combusting 100% ammonia by 2025. 94 Similar to green hydrogen, NOx is controlled using SCR systems that are in common use today.

**RNG and Derivatives Thereof**

RNG can be used to fuel dispatchable, gas-fired electric generating plants to meet system reliability needs. 95 RNG is derived from sources such as municipal solid waste landfills, digesters at water recovery facilities, livestock farms, food production facilities, and organic waste operations. 96 RNG is gas collected from sources already producing and releasing bio-derived methane, thereby eliminating already occurring methane emissions into the atmosphere. 97 RNG is created by removing moisture, carbon dioxide (“CO2”), and trace-level contaminants from raw biogas and reducing the nitrogen and oxygen content to reach a methane content of approximately 96% to 98%. 98 Methane’s climate impact is more than 25 times the impact of CO2. 99 By combusting the methane and producing CO2 as a byproduct, lower GHG emissions are achieved compared to simply releasing the methane into the atmosphere. 100 On a net basis, GHGs emissions from RNG are less than zero, based on methane’s impact being greater than CO2. 101 The benefits of RNG have been recognized in governmental programs, such

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95 Aff. at ¶ 28.

96 Aff. at ¶ 28.

97 Aff. at ¶ 28.

98 Aff. at ¶ 28.

99 Aff. at ¶ 28.

100 Aff. at ¶ 28.

101 Aff at ¶ 28.
as the EPA’s Landfill Methane Outreach Program and its AgSTAR Program, which work with various industries to avoid methane emissions by supporting biogas energy projects.102

Renewable diesel can be produced from biomass feedstocks through hydrotreating, gasification, pyrolysis, and other biochemical and thermochemical technologies.103 Renewable propane can be made from the same byproducts used to create biofuels.104 The most common feedstock is a byproduct of renewable diesel and sustainable aviation fuel made from plant and vegetable oils, animal fats, or used cooking oil.105 Methanol is another biofuel that can be used to fuel dispatchable electric generating facilities to maintain grid reliability.106 Generating facilities that combust diesel can be converted to operate on methanol.107

In response to parties’ opposition to Consolidated Edison Company of New York, Inc.’s (“Con Edison”) proposal to interconnect its natural gas system with local RNG supplies in its recent gas rate case, the Commission noted that the Scoping Plan acknowledged that RNG may be considered to “decarbonize the gas system as it transitions.”108 The Commission also pointed to its CLCPA Implementation Order,109 in which it recognized RNG may be needed “as a tool to reduce the carbon content of gas as the State implements strategies for long-term decarbonization

102 Aff. at ¶ 28.
103 Aff. at ¶ 29.
104 Aff. at ¶¶ 29–30.
105 Aff. at ¶ 30.
106 Aff. at ¶ 29.
107 Aff. at ¶ 29.
and transition of the gas system, to continue to meet the energy needs of hard to electrify customers, and to meet the goals of the CLCPA.\textsuperscript{110} The Commission also dismissed arguments that RNG should be rejected because it is prone to leaking. The Commission ruled that Con Edison’s efforts to replace leak-prone pipe, its new installation of pipe for this project, and the displacement of fossil fuels transported from farther away help to ensure the project will not cause increased leaks and GHG emissions.\textsuperscript{111} The Commission found Con Edison’s proposal beneficial because Con Edison will investigate using RNG as a means of reducing GHG emissions.\textsuperscript{112}

Thus, the Commission should designate RNG and its derivatives discussed above as zero emissions sources that satisfy the 2040 Zero Emissions Target.

**Demand Response**

Demand response resources are programs and technologies designed to reduce or shift consumer usage during peak periods in response to financial incentives. Demand response can reduce the need to utilize non-zero emission sources to meet load demand.\textsuperscript{113} Intermittent renewable generation dispatch curves are commonly referred to as “duck curves,” where dispatch is high in the morning, drops off mid-day, increases in the evening, and then drops off again at night.\textsuperscript{114} Incentives that encourage consumers to switch usage to lower-usage periods can reduce demand during peak periods and, in effect, act as a valuable zero emissions

\textsuperscript{110} Id. at 28.

\textsuperscript{111} Order Adopting Joint Proposal at 128.

\textsuperscript{112} Id. at 129.

\textsuperscript{113} Aff. at ¶ 32.

\textsuperscript{114} Aff. at ¶ 32.
dispatchable resource.\textsuperscript{115} Thus, the Commission should designate demand response resources as zero emissions sources that satisfy the 2040 Zero Emissions Target.

**CCUS and DAC**

CCS and carbon capture and utilization (“CCU”) are often collectively referred to as carbon capture, utilization, and storage (“CCUS”). CCUS is a technology that can capture CO\textsubscript{2} from fossil fueled generating facilities and permanently store or utilize it in beneficial alternative substances and products. Generally, for combustion turbines and utility boilers, CCS removes CO\textsubscript{2} from the exhaust gas after combustion and then compresses and transports it, typically through pipelines, to a site for geologic sequestration.\textsuperscript{116}

Natural gas generators utilizing CCS can remove 95\% to 98\% of CO\textsubscript{2} emissions.\textsuperscript{117} To date, a total of more than a quarter of a billion tons of CO\textsubscript{2} has been captured and stored globally by these technologies, and more than gigaton of CO\textsubscript{2} has been transported for use or storage.\textsuperscript{118} In 2022, 46 million metric tons of CO\textsubscript{2} from energy production industries, globally, were captured and geologically stored\textsuperscript{119} and the DOE projects that by 2030, CCS technologies will capture and store 254 million metric tons of CO\textsubscript{2} per year globally.\textsuperscript{120} This increase in stored CO\textsubscript{2} pales in comparison to the amount used to produce more oil at existing oil wells, and there is a growing secondary market for sequestered carbon.

\textsuperscript{115} Aff. at ¶ 32.

\textsuperscript{116} EPA Proposed GHG Rule at 33254.

\textsuperscript{117} Aff. at ¶ 33.


\textsuperscript{119} Aff. at ¶ 35.

\textsuperscript{120} Aff. at 35.
The EPA Proposed GHG Rule put forward that “CCS with a 90 percent capture rate has been adequately demonstrated and is technically feasible based on the demonstration of the technology at existing coal-fired steam generating units and industrial sources in addition to combustion turbines.”

The EPA explained that multiple existing fossil fuel power plants are considering adding CCS, and that CO₂ pipelines are available, with an expanding network in the United States, and “[a]reas without reasonable access to pipelines for geologic sequestration can transport CO₂ to sequestration sites via other transportation modes such as ship, road tanker, or rail tank cars.”

The EPA also stated that “geologic sequestration of CO₂ is well proven, broadly available throughout the U.S., and there is a detailed set of regulatory requirements to ensure the security of sequestered CO₂.” Finally, the EPA noted that technology advancements and new policies, including the significant expansion of the Internal Revenue Code Section 45Q tax credit for CCS in the Inflation Reduction Act, have decreased the costs of CCS.

A viable alternative to CCS is CCU, also potentially with a near net zero footprint. CCU differs from CCS in that CCU does not result in the permanent geological storage of CO₂ but instead converts captured CO₂ into beneficial alternative substances and products. Examples of CCU being explored today include utilizing CO₂ to help produce plastics, protein, rock, formic acid, clothing, fertilizer, and carbon neutral fuel. CCU is employed in some settings in this

121 EPA Proposed GHG Rule at 33367.
122 EPA Proposed GHG Rule at 33368.
123 EPA Proposed GHG Rule at 33366.
124 EPA Proposed GHG Rule at 33245.
125 7 ways CO₂ can be recycled and reused, Energy Factor Asia Pacific Newsletter (Jan. 18, 2023).

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CCU, like CCS, is viable and evolving and should be included in the definition of “zero emissions.” Given the geology of New York, CCU may ultimately prove to be more feasible than CCS.

DAC technologies use chemical reactions to extract CO₂ directly from the atmosphere at any location—unlike CCS, which is generally carried out at the point of emissions. The removed CO₂ can be permanently stored in deep geological formations or used for a variety of applications including for synthetic fuel purposes. A major advantage to this technology over CCS is its ability to be independently located in geographical areas best suited for long-term CO₂ sequestration, which may prove promising for the geographically constrained New York City area. The DOE Office of Clean Energy Demonstrations has established four regional DAC Hubs designed to provide $3.5 billion in funding for eligible projects that contribute to the development of this technology, and the Section 45Q tax credit is equally available to DAC as it is to CCS. In Texas, Occidental Petroleum Corp. and 1PointFive, Inc. are developing DAC projects with the potential to remove and store up to 30 million metric tons of CO₂ per year.

3. How should a program to achieve the Zero-Emission by 2040 Target address existing and newly constructed nuclear energy resources? Should the program be limited to specific types of nuclear energy technologies and exclude others?

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Nuclear generation resources emit no GHGs during operation and the Commission has previously recognized the zero emissions attributes of the upstate nuclear fleet in its Order Adopting a Clean Energy Standard.\textsuperscript{130} Nuclear facilities already play a large zero-emissions role in the State’s energy mix—in 2022, 44% of New York’s zero emission electricity was generated by nuclear facilities.\textsuperscript{131} According to the Nuclear Energy Institute, 19% of electricity in the United States generated in 2021 was provided by nuclear facilities\textsuperscript{132} and therefore avoided more than 476.5 million tons of CO\textsubscript{2}.\textsuperscript{133} After hydropower, nuclear power is the second largest source of zero-emission power.\textsuperscript{134} Further, the low marginal cost and its current mode of operation allow existing nuclear facilities to operate primarily at baseload, providing vast amounts of around-the-clock zero-emission power with capacity factors of 92.7% or greater in 2021.\textsuperscript{135}

The nuclear energy industry is advancing new nuclear plants to accommodate increasing levels of intermittent renewables by designing plants to be more flexible—following load and daily variations of demand.\textsuperscript{136} Small nuclear reactors (“SMRs”) are being developed that provide more flexible operation. Several SMRs co-located at one site would also provide more

\textsuperscript{133} Aff. at ¶ 36 (citing \textit{Emissions Avoided by U.S. Nuclear Industry}, Nuclear Energy Institute (last updated Aug. 2022), \url{https://www.nei.org/resources/statistics/old/emissions-avoided-by-us-nuclear-industry}).
\textsuperscript{134} Aff. at ¶ 36.
\textsuperscript{135} Aff. at ¶ 37 (citing, \textit{What is Generation Capacity}, U.S. DOE Office of Nuclear Energy (May 1, 2020), \url{https://www.energy.gov/ne/articles/what-generation-capacity?#:~:text=The%20Capacity%20Factor&amp;text=A%20plant%20with%20a%20capacity%20of%20the%20time%20in%202021.). Constellation, the owner of the State’s four nuclear facilities, reported a fleet-wide capacity factor of 94.8% in 2022. \textit{Testimony of Joseph Dominguez President & Chief Executive Officer, Constellation Energy, to United States Senate Committee on Energy and Natural Resources} (Mar. 9, 2023), \url{https://www.energy.senate.gov/services/files/0E076807-6F7F-4C0A-8D21-8E7E0A7ACF25}.
\textsuperscript{136} Aff. at ¶ 40.
flexibility. For example, 12 of NuScale Power Corporation’s power modules at the DOE’s Idaho National Laboratory will generate 720 MWe and are designed with the “flexibility to ramp up and down as needed to follow load and complement intermittent renewable supply.”

According to Mr. Cohn, depending on their design and applicable regulations, modifications to existing nuclear plants may also provide flexible operation. The Scoping Plan acknowledges the value proposition of nuclear generation in achieving the State’s clean energy goals and, according to the accompanying Technical Supplement, assumes the State’s existing upstate nuclear fleet receives 20-year Nuclear Regulatory Commission license extensions. The Scoping Plan recommends that the State should evaluate the role of existing and advanced nuclear facilities prior to the scheduled conclusion of the ZEC program in 2029 while also recognizing the requisite time to relicense and refuel these facilities.

Therefore, policy mechanisms to preserve New York’s existing generation fleet and incentivize next generation nuclear technologies should be advanced to capture this critical, emission-free technology.

4. Should new measures adopted to pursue compliance with the Zero-Emission by 2040 Target focus exclusively on generation and resource adequacy, or should they also encompass a broader set of technologies that could be integrated into the transmission or distribution system segments, or installed and operated behind-the-meter?

Compliance with the 2040 Zero Emissions Target will require a broader set of technologies to provide reliability. As Mr. Cohn explains in his affidavit, “grid stability is

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138 Aff. at ¶ 40.

139 Scoping Plan, App’x G at 92.

140 Scoping Plan at 79, 254, and 256.
currently provided with dispatch control of large thermal plant rotating synchronous
generators.”141 As thermal generators are retired or taken out of service, grid stability must be
accomplished with control of considerably more sources through communication with dispatch
control than occurs presently. As behind-the-meter resources, such as distributed solar, are added
to the system, the grid must have the means to balance supply and demand. Specifically, supply
and demand balance will need to be achieved when the sun sets and contribution from solar
resources drop rapidly.142 As discussed above, the duck curve is commonplace in systems with
large-scale solar resource penetration and “shows the difference in electricity demand and
amount of available solar energy during the day.”143 System integration to manage the
challenges of the duck curve’s extreme swings, when variable renewable generation drops off,
will be required and the DOE’s Solar Technologies Office is studying this very challenge.144

Dynamic Line Ratings is a technology that can be used to manage congestion and
increase grid resilience and reliability by changing the amount of current that can flow through
an electric transmission line in response to real-time weather conditions.145

Another potential technology to address the challenges of increased intermittent
generation is VPPs. VPPs are an aggregation of DERs that are equipped with “smart” inverters,
allowing utilization to be coordinated by a centralized control and communications system.146
Typically, VPP resources are “comprised of residential or commercial rooftop solar and lithium-

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141 Aff. at ¶ 43.
142 Aff. at ¶ 43.
143 Aff. at ¶ 43.
144 Aff. at ¶ 43.
145 Aff. at 44 (citing Dynamic Line Rating Systems for Transmission Lines, DOE (Apr. 25, 2014), at i,
146 Aff. at ¶ 45.
ion battery energy storage systems, but may also include other ‘smart’ devices, such as electric vehicle chargers, thermostats, and [household appliances].”

Additionally, the grid services VPPs deliver will yield carbon emission-reduction benefits. VPPs can facilitate demand response programs. Technologies that optimize demand response, within a VPP, can more efficiently balance the overall energy demand with the available renewable energy supply, thereby reducing the need for conventional fossil fuel power plants that would otherwise be needed during peak demand periods. VPPs that incorporate energy storage systems could store excess energy during high renewable energy generation periods and then dispatch the stored energy during high demand periods or when renewable energy availability is low. VPPs can also offer ancillary services, such as frequency regulation and voltage. Accordingly, VPPs can enhance grid stability, minimize renewable energy curtailment, and reduce the need for carbon-intensive backup power sources.

5. **Should any program to achieve the Zero-Emission by 2040 Target specify subcategories of energy resources based on particular characteristics, such as ramp rates, the duration of their operational availability, or their emissions profile with respect to local pollutants?**

The Commission’s program should incent the type of zero emitting resources that can provide the services required to maintain the reliability of the grid. It is important for grid system reliability to, among other things, match generation supply with electricity demand, match the changes in demand with changes in supply, provide reactive power support to match

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147 Aff. at ¶ 45.
148 Aff. at ¶ 45.
149 Aff. at ¶ 45.
150 Aff. at ¶ 45.
the overall difference in phase between electrical system voltage and current, support
maintenance of system frequency, and support maintenance of system voltages.

According to the NYISO, grid strength is a common term to describe how the system
responds to system changes. In a strong system, voltage and frequency are relatively
insensitive to injection changes by inverter-based renewable resources. In addition, the ability
of inverter-based resources to properly function frequently depends on the strength of the grid.
The NYISO’s 2021–2030 Comprehensive Reliability Plan noted that “the stability of the grid
could weaken as conventional synchronous generation retires” and identified weak portions of
the grid that, without mitigation measures, are likely to experience system performance issues.
This system weakening is caused by a number of factors, including “the loss of, or change in,
location of reactive power resources, the lack of transmission facilities to transmit the energy to
load, and/or the reduction in primary frequency response due to the loss of system inertia from
the retirement of legacy synchronous generation.”

Due to their intermittent nature, renewable energy systems have minimal ability to
provide grid strengthening services. Rotating synchronous machines currently provide
reactive power, frequency, and voltage support to the electric system. These resources provide
the necessary inertia to counteract changes in voltage and frequency. “Power system inertia” is
defined as the ability of a power system to oppose changes in system frequency due to resistance

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152 Id.
153 Id.
154 Id. at 44.
155 Aff. at ¶ 47.
156 Aff. at ¶ 47.
provided by rotating masses. As penetration levels of non-synchronous, inverter-based generation resources (e.g., wind, solar, and batteries) increases, a system’s inertia will decline.

According to a report by National Renewable Energy Laboratory, inertia can also be maintained by operating a grid in a matter to ensure that the mix of generators online exceeds critical inertia levels. However, this option can have negative economic consequences because it requires increasing the number of power plants online and operating at partial load, as well as the curtailment of intermittent resources. Some renewables like hydroelectric, geothermal, and (in some cases) wind generators can provide inertia if equipped with excitation systems, which can be modified to meet electrical system reactive power requirements. “Battery-inverter systems can also be provided with controls to compensate frequency variations and to provide voltage and reactive support.”

Synchronous generators of existing thermal facilities may also be used to supply inertia and reactive power—turning decommissioned facilities into “synchronous condensers.” “Synchronous condensers are formed by uncoupling the generators from their prime movers, starting them as synchronous motors, and then synchronizing them.”

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158 Id.
160 Id.
161 Aff. at ¶ 47.
162 Aff. at ¶ 47.
163 Aff. at ¶ 48.
164 Aff. at ¶ 48.
reactive power control and inertia to the electric system, which, in turn, can dampen transient fluctuations in frequency and voltage.  

6. **What role does technology innovation need to play to meet the CLCPA’s Zero-Emission by 2040 Target?**

Technology innovation must play a primary role to achieve the 2040 Zero Emissions Target because DEFRs, currently unavailable, must be developed for commercial deployment in the near future. The NYISO stated that DEFRs “represent a proxy technology that will meet the flexibility and emissions-free energy needs of the future system but are not yet mature technologies that are commercially available” and pointed to hydrogen, RNG, and SMRs as examples of potential DEFRs. In its Outlook, the NYISO concluded that DEFRs will be essential in maintaining a reliable electric grid but are not commercially available today.

In the Outlook, the NYISO developed two Policy Case scenarios to reflect full achievement of the CLCPA targets, both of which assume that all existing fossil generators will be retired by 2040. In both scenarios, the NYISO concluded that as more wind, solar, and storage resources are added to the grid, DEFRs must be added to complement these resources and “meet the minimum statewide and locational resource requirements for serving system demand when intermittent generation is unavailable.” Specifically, to reach the targets, Scenario 1 builds approximately 45 GW of DEFRs and Scenario 2 builds approximately

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165 Aff. at ¶ 48.


167 Id. at 12.

168 Id. at 9. Scenario 1 assumes a 57,144 MW winter peak and 208,679 GWh energy demand in 2040, and Scenario 2 assumes a more moderate peak but a higher overall energy demand (42,301 MW winter peak and 235,731 GWh) energy demand in 2040.

169 Id. at 10.
27 GW. In another scenario excluding DEFRs as a technology option, the NYISO found the 45 GW of DEFRs built in Scenario 1 would need to be replaced by 30 GW of offshore wind and 40 GW of energy storage.

The NYISO stated that, due to the lead time necessary to commercialize, develop, permit, and construct DEFRs, action is required soon to achieve the CLCPA targets because “such lead times necessary for these technologies may extend beyond policy target dates.” As discussed above, potential DEFR technologies are in various stages of development and will require significant public and private investment to reach system-scale commercialization.

The higher integration of variable renewable energy will also increase the need for more flexibility and energy storage. However, a commonly used battery storage technology, lithium-ion (“Li-ion”) batteries, presents feasibility concerns as it is increasingly deployed at scale, including challenges related to the limited supply chain, manufacturing process, and safety. The United States does not currently produce lithium or have a large reserve of the cobalt used for Li-ion batteries. As Mr. Cohn explains in his affidavit, a domestic supply through recycling will be needed to mitigate this supply risk. Mr. Cohn also states that new approaches to component design will be needed to increase energy density and reduce costs. Li-ion batteries are also known to overheat and explode under certain conditions and, therefore,
more research is required for the most economic and safe approach to the wide-scale grid
deployment of batteries.\textsuperscript{177}

Accordingly, innovation, research, and investment are needed to achieve the CLCPA targets. Mr. Cohn identified several nascent energy storage technologies that should also be considered as tools to reach the CLCPA targets: molten salt, compressed air, flywheels, and tidal energy.\textsuperscript{178} Molten salt storage technologies store heat, and generate electricity from the stored heat between 8 and 24 hours.\textsuperscript{179} Heat energy from the grid, a nearby power plant, or heat pumps provide the energy to store heat and has been demonstrated in concentrated solar power projects worldwide.\textsuperscript{180} For example, a company has developed a concept for a 100 MW, stand-alone molten salt energy storage system using electricity from the grid and heat pumps, and has made an agreement with the Orlando Utilities Commission of Orlando, Florida, to develop the project.\textsuperscript{181}

Flywheels\textsuperscript{182} can store electrical energy as rotating inertia.\textsuperscript{183} Flywheels are limited to short-term applications, such as spinning reserve for grid frequency. The world’s largest flywheel, Ireland’s Moneypoint Power Station, was installed in 2022 and has a mass of 130 tons

\textsuperscript{177} Aff. at ¶ 52.
\textsuperscript{178} Aff. at ¶ 52.
\textsuperscript{179} Aff. at ¶ 53.
\textsuperscript{180} Aff. at ¶ 53.
\textsuperscript{181} Id. (citing Press Release, Malta Inc. and Orlando Utilities Commission Collaborate on Long-Duration Energy Storage, Malta Inc. (Jan. 5, 2023), \url{https://maltainc.com/news/2023/01/malta-inc-and-orlando-utilities-commission-collaborate-on-longduration-energy-storage--/}).
\textsuperscript{183} Aff. at ¶ 54.
and can rotate up to 3,000 rotations per minute.\textsuperscript{184} Additionally, a storage project in the Netherlands in 2022 combined a 10 MW battery with a 3 MW flywheel to maintain grid frequency.\textsuperscript{185}

Compressed air energy storage ("CAES") compresses and stores air under pressure in underground caverns or above-ground containers and then converts the hot compressed air into thermal and mechanical energy.\textsuperscript{186} In a diabatic CAES plant, the heat generated is removed by coolers and then heated during the expansion phase in a gas turbine generator to produce electricity. Two diabatic CAES plants are in operation: a 320 MW plant in Germany, and a 110 MW plant in the United States. In addition, Hydrostor Inc. is planning to build two plants in California and one plant in Australia.\textsuperscript{187}

Flow batteries use a liquid solution to store energy and have less sensitivity to deep discharge, a longer life cycle, and unlimited energy capacity.\textsuperscript{188} Flow batteries may be a necessary grid technology as an alternative technology to lithium-ion batteries and, as Mr. Cohn noted, are more suitable to larger energy-to-power requirements.\textsuperscript{189} Challenges in developing flow batteries include manufacturing technologies, standard supply chain, and scale-up.\textsuperscript{190}

Regarding manufacturing, components are currently expensive and additional research will be

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\textsuperscript{185} PV Magazine, Dutch startup stabilizes Netherland’s grid with 9 MWh battery-flywheel storage facility, October 4, 2022.
\textsuperscript{187} Aff. at ¶ 56–57.
\textsuperscript{188} Aff. at ¶ 62.
\textsuperscript{189} Aff. at ¶ 62.
\textsuperscript{190} Aff. at ¶ 62.
\end{flushright}
needed to optimize manufacturing and reduce cost.\textsuperscript{191} Regarding the supply chain, the current technology relies on expensive vanadium, which is mostly imported and limited in supply. and regarding scale-up, a manufacturing process supporting larger deployments has yet to be developed.\textsuperscript{192}

Linear generators, a new category of flexible generating technology developed by Mainspring Energy, Inc., can generate electricity using fuels such as green or pink hydrogen, ammonia and RNG.\textsuperscript{193} As the generator does not combust the fuels, there are no NO\textsubscript{x} emissions. The Linear generators can be used for long-duration storage (days, weeks, or seasons) and as peaking facilities. They are an inverter-based technology, so they can be used to create VPPs, operated as DERs, or utilized as demand response resources.

Tidal energy harnesses the flow of ocean currents and tides to generate electricity.\textsuperscript{194} These technologies are nearing commercialization, and the range of tidal energy technology is between 0.1 MW and 2 MW.\textsuperscript{195} Since 2010, more than 26.8 MW of tidal energy technology has been developed in Europe, with 11.9 MW currently in operation.\textsuperscript{196}

Fuel cells, which are DERs, powered by renewable biogas are eligible renewable energy systems under the CLCPA and provide reliable, 24/7 renewable power based on mature

\textsuperscript{191} Aff. at ¶ 62.
\textsuperscript{192} Aff. at ¶ 62.
\textsuperscript{195} Aff. at ¶ 63.
\textsuperscript{196} Aff. at ¶ 63; see also \textit{ETP Clean Energy Technology Guide}, IEA (July 12, 2023), \url{https://www.iea.org/data-and-statistics/data-tools/etp-clean-energy-technology-guide}. 

technology that reduces emissions today. Fuel cells197 convert hydrogen to electricity and heat, producing only water and no direct emissions.198 Because fuel cells provide clean baseload power, when configured as part of a microgrid, they can isolate facilities during outages and keep critical facilities online while avoiding the need to operate backup fossil generation.

7. **Should life cycle emissions impacts be considered when characterizing energy resources? If so, how?**

Life cycle analysis (“LCA”) is a method to evaluate the environmental impact of a product throughout its life cycle. Typically measured in GHG emissions, LCA evaluates the environmental impact of the extraction and processing of raw materials, manufacturing, distribution, use, recycling, and final disposal of a product. Historically, LCAs have focused on products, not overall projects or electric resources. Mr. Cohn stated in his affidavit that developing an LCA for a generation resource is much more complex than for a manufactured product because it requires aggregation of many different materials and processes into one project.199 For example, an LCA estimate for cement used at a generation facility would have to include the LCA for the source, production, and transportation of that cement. To develop an LCA for an entire generation facility, an LCA would need to be developed for hundreds of other raw materials, equipment, and components required to construct and operate the facility.200

Depending on the project and application, an LCA can be performed by a wide range of programs (such as OpenLCA, GREET, and SimaPro) or by direct calculation.201 Whether by

198 Aff. at ¶ 64.
199 Aff. at ¶ 66.
200 Aff. at ¶ 66.
201 Aff. at ¶ 67.
program or direct calculation, a very large number of inputs need to be defined, and the level of detail and source of that input can vary widely for each technology and for each project considered. For example, OpenLCA, the program developed by the National Energy Technology Laboratory suggested that, for DOE-funded CCS projects, the products must be inputted, which can be sourced from a database of product systems and have a wide range of associated GHG emissions.202

If life cycle emissions impact is to be considered as part of the compliance with the 2040 Zero Emissions Target, there must be consistency across all technologies being evaluated. Due to the wide ranges of GHG assumptions that are used to make LCA estimations, overall complexity of the analysis, and the difficulty of accurately determining the LCA for implementation of a particular facility, LCA should not be a major consideration in the characterization of utility-scale emissions sources.203

8. Given that the feedstocks and other resources required to produce renewable natural gas are limited and will be in demand in other sectors of New York’s economy, how should this fuel be considered in the context of this proceeding?

As discussed above and in Mr. Cohn’s affidavit, RNG is a high-British thermal unit (“Btu”) gas from the decomposition of organic material that has been processed to a gas, which is fully interchangeable with natural gas and can be injected into a natural gas pipeline.204 With 230 RNG projects operating in 2022, the technology is considered mature.205 For example, landfill gas (“LFG”) was recovered and processed into high-Btu RNG and directly injected into

202 Aff. at ¶ 68.
203 Aff. at ¶ 69.
204 Aff. at ¶ 70.
205 Aff. at ¶ 70.
the National Grid pipeline for more than 30 years at the Fresh Kills Landfill in Richmond, New York, prior to the landfill’s closure in 2002.206

Municipal solid waste (“MSW”) landfills are the third-largest, human-generated source of methane emission in the United States.207 Technologies or applications that reduce methane emissions from MSW landfills (estimated at an equivalent of 103.7 million tons of CO₂ in 2021—equivalent to emissions from 23.1 million gas-powered passenger vehicles driven for one year) will contribute to mitigate global climate change.208 LFG is either released into the atmosphere undisturbed, collected to be flared, or used in an LFG energy project.209 Treatment of LFG removes impurities and compresses the gas to RNG that can be injected into a natural gas pipeline. About 16% of currently operating LFG energy projects create RNG.210

RNG feedstock can be considered as a “drop-in” fuel for gas turbines to provide dispatchable generation. As discussed supra, a NYISO analysis revealed that, by 2040, there will be a need for 27 GW to 45 GW of DEFRs and that “[i]t is especially important to note that commercially available technologies to provide dispatchable, non-emitting supply do not exist at scale at this time.”211 With 50% of the Achievable Deployment from Anaerobic Digestion and Thermal Conversion212 used to fuel gas turbines, RNG could provide an estimated 5.80% of the

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208 Id.
209 Aff. at ¶ 72.
210 Aff. at ¶ 72.
dispatchable generation needed for 27 GW and 3.5% for 45 GW. Accordingly, RNG can be used as a dispatchable source to maintain grid reliability when renewables and battery storage do not meet electric demand. This should be considered as one of many “all of the above” strategies to provide zero emitting dispatchable generation to help meet the 2040 Zero Emissions Target.

9. In what ways might a program to meet the Zero-Emission by 2040 Target require reexamination and possibly revision of different tiers of the Clean Energy Standard? Should one or more of the policy approaches that have been used to implement the CES be considered to meet the Zero-Emission by 2040 Target?

The CES requires load-serving entities to help New York meet its clean energy and climate goals by purchasing clean energy attributes: Renewable Energy Credits (“RECs”) to support new renewable generating facilities and ZECs to support existing nuclear generating facilities. As stated in the Scoping Plan, “the 100x40 requirement presents significant challenges that cannot currently be met by the deployment . . . of existing technologies” such as energy efficiency, renewables and energy storage technologies.213 The technologies that IPPNY recommends herein, such as RNG, CCUS, DAC, nuclear, and hydrogen, and as discussed within the Scoping Plan, have the potential to close the gap between the capabilities of existing renewable energy technology and expected future system reliability requirements.214 To ensure those technologies are fully capable to provide the necessary operating flexibility by 2040, significant investment and incentivization will be required.

Thus, the Commission should establish a new tier under the CES specifically to incent the deployment of the zero emission resources that the Commission identifies in this proceeding to help meet the 2040 Zero Emissions Target. The Commission should direct NYSERDA to begin conducting annual competitive solicitations as soon as possible to procure ZECs from

213 Scoping Plan at 252.
214 Aff. at ¶ 76.
eligible zero emissions resources, without impairing the current REC or ZEC programs. To jumpstart the significant investment to upgrade and retrofit existing facilities that will be needed to develop the necessary infrastructure to support the combustion of green hydrogen, the Commission should require NYSERDA to solicit resources that can soon begin co-firing small volumes of green or pink hydrogen with natural gas as early as 2032 and no later than 2038, to meet the requirements of the EPA Proposed GHG Rule, with a phase-in to 100% green or pink hydrogen by 2040. The solicitations will provide valuable information to the Commission regarding the technical and economic feasibility of these technologies to support the reliability of the electric system through the clean energy transition and will allow these technologies to become available in time to meet the 2040 Zero Emissions Target.

10. What is necessary to align a program to meet the Zero Emission by 2040 Target with the priority of just transition embedded within the CLCPA?

A program to meet the Zero Emission by 2040 Target must account for employment impacts because renewable energy systems typically require fewer operating personnel than traditional thermal power plants. As Mr. Cohn stated in his affidavit, “generation facilities, utilizing net zero GHG emissions technologies such as new nuclear, hydrogen, CCS, and RNG, will require similar numbers of operating staff with similar training as existing thermal and nuclear power stations.”

The Commission should require quality-based contracting and labor provisions that facilitate timely, successful project delivery, while also promoting the vital Just Transition goals.


216 Aff. at ¶ 76.
of the CLCPA. Such provisions that should be incorporated into future planning for this program include prevailing wage standards, apprenticeship requirements, and project labor agreements (“PLAs”), as well as labor peace and Buy American provisions.

Prevailing wage, apprenticeship training, and PLAs have a long history of success in public and publicly assisted construction programs in New York and nationally and have provided substantial assistance in building numerous types of power generation projects. These provisions are some of the most effective tools available to aiding project delivery because they help ensure that projects are built in a safe, cost-effective manner and meet applicable standards and critical construction and power generation schedules. Buy American and labor peace provisions also provide substantial benefits by promoting valuable employment and training opportunities in local communities. Thus, when properly designed and administered, these policies can offer a true path to Just Transition for workers in the energy sector.

Accordingly, the Commission should require that the owner, or a third party acting on the owner’s behalf, of the zero emissions resource comply with the provisions of PSL § 66-r and New York State Labor Law § 224-d as an ongoing condition of any agreement to implement the zero emissions energy program. The Commission should also require that bona fide apprenticeship programs—registered with the United States Department of Labor or State apprenticeship agencies—are utilized by requiring all contractors and subcontractors on affected projects to participate in apprenticeship training programs for each craft or trade in which they employ workers.

This approach builds on the Just Transition strategy embraced in the 2021 to 2022 State Budget, which adopted such policies for renewable energy systems through key amendments to
the PSL and Labor Codes.\textsuperscript{217} These policies have also been embraced in prior Commission decisions,\textsuperscript{218} as well as recent legislation launching pilot programs for Thermal Energy Networks, an initiative passed with overwhelming bipartisan support and promoted by an extremely broad based coalition of utilities, business, labor groups, and environmental groups.\textsuperscript{219}

This proposal is consistent with the March 23, 2021, recommendations of the Just Transition Working Group to the Climate Action Council.\textsuperscript{220} It would create and retain good paying union jobs in New York, spur local manufacturing, further New York’s clean economy goals, help encourage the repurposing of existing facilities, and incentivize private investment in new, zero carbon emission technologies that strengthen local communities. A Just Transition to clean energy can only occur if workers in this sector are allowed to participate in the zero-emissions energy future.

In addition, existing or future generating sites in Disadvantaged Communities should continue to host ambient air quality measurement stations to track progress in improving air quality. DEC is conducting its 2022–23 Statewide Community Air Monitoring Initiative\textsuperscript{221} in 10 communities, which were identified as having a disproportionate air emission burden. The

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\textsuperscript{217} See PSL § 66-r; N.Y. Labor Law § 224-d; State Education, Labor, Housing and Family Assistance Budget Bill for the 2021–2022 State Fiscal Year, 2021 N.Y. Sess. Laws Ch. 56 (McKinney), Part AA, § 2-a.
\textsuperscript{218} See e.g., Case 18-E-0071, In the Matter of Offshore Wind Energy, Order Establishing Offshore Wind Standard and Framework for Phase 1 Procurement (July 12, 2018) (“PLAs may be particularly valuable in the context of offshore wind procurements where time is of the essence [as they help] assure timely compliance with contract terms and delivery of power . . . .”).
\textsuperscript{221} DEC is undertaking a statewide community air quality monitoring effort in 10 disadvantaged communities and has contracted with Aclima to measure air pollution from sources such as cars, diesel trucks, construction equipment, commercial sources, and industrial facilities. 2022–23 Statewide Community Air Monitoring Initiative, DEC, https://www.dec.ny.gov/chemical/125320.html (last visited Aug. 15, 2023). Furthermore, power plant owners already monitor and report their stack emissions to the EPA and the DEC.
\end{flushleft}
existing CLCPA requirement for 40% of program economic benefits to go to Disadvantaged Communities would provide incentives for the development of zero emission resources in these communities.

11. How might the benefits of a program to meet the Zero-Emission by 2040 Target be measured for the purpose of ensuring that, consistent with PSL § 66-p(7), it delivers “substantial benefits” to Disadvantaged Communities?

Benefits to Disadvantaged Communities should be measured by air quality improvements as determined via the DEC’s 2022–23 Statewide Community Air Monitoring Initiative and by implementing the CLCPA requirement for 40% of program economic benefits to go to Disadvantaged Communities to ensure those communities are delivered “substantial benefits” by a zero-emissions program. Many of the fossil fuel generators in the State are located in Disadvantaged Communities. By incentivizing and investing in net-zero emissions technologies, these fossil fuel generators can be retrofitted to be, or replaced with, net-zero emissions technologies that improve local air quality in those communities, which leads to better health and lower healthcare bills.\(^{222}\) The measurement of benefits should also, as discussed above, consider the fact that zero-emissions technologies such as new nuclear, hydrogen, RNG, and CCUS provide more employment opportunities than renewable technologies such as solar and wind and will require similar numbers of operating staff with similar training as existing thermal and nuclear power stations.

12. NYISO has adopted an effective load carrying capacity (ELCC) rubric and treatment of Zones J and K as load pockets with special resource adequacy requirements. How should these constructs and other NYISO market rules inform the design of a program meant to support the development and deployment of resources capable of achieving a zero emissions grid?

A program to support resources capable of achieving a zero emissions grid should be designed to incent the resources having the attributes that the NYISO’s market rules most value to support system reliability. As the NYISO’s market design constructs evolve to address the reduction of fossil fuel generation, so, too must the Commission’s programs to ensure the zero emissions resources with the needed attributes enter the market at the right time and at least cost and their ongoing operations can be supported efficiently.

One such construct is the NYISO calculation of Capacity Accreditation Factors which are designed to reflect the marginal reliability contribution of capacity market suppliers within each Capacity Accreditation Resource Class (“CARC”). A CARC is a defined set of resources with similar technologies and/or operating characteristics that are expected to have similar marginal contributions toward meeting the New York State Reliability Council’s resource adequacy requirements. The results of this annual calculation affect the capacity market revenues a generator can make, thereby sending a price signal to developers that incentivizes construction of generation resources that most efficiently contributes to system reliability. Other constructs include the development of new, and the refinement of existing, ancillary service products. As the NYISO noted in the Outlook, because there will be a greater need for flexible resources during the transition to an emissions-free grid, “[c]oordination of renewable energy additions,

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commercialization, and development of DEFRs, and fossil fuel plant operation over the next 18-years will be essential to facilitate an orderly transition of the grid.”\textsuperscript{224}

13. **What additional studies, if any, should the Commission undertake with respect to the development and deployment of resources capable of achieving a zero emissions grid?**

Maintaining system reliability should be a driving force as New York determines which zero emissions resources are necessary to meet the 2040 Zero Emissions Target. To that end, the Commission and the NYISO should undertake studies to identify the quantity and characteristics of needed resources as the generating mix and grid evolves. These studies should be conducted on a regular and ongoing basis during the transition to a zero emissions electric system to ensure development is proceeding apace and a reliable system will be maintained throughout the transition to, and after, the State achieves its zero emissions target.

The NYISO currently undertakes two methods to determine reliability needs. Regarding short-term reliability needs, NYISO conducts a quarterly STAR.\textsuperscript{225} STAR focuses on identifying reliability needs up to five years out, which helps evaluate imminent needs of the grid in light of ongoing changes to the energy landscape. Regarding long-term reliability needs, NYISO conducts the Reliability Needs Assessment (“RNA”) once every two years.\textsuperscript{226} The RNA focuses on identifying reliability needs up to ten years out to consider the adequacy of energy resources and limitations on the transmission grid. Using this data, the Commission and NYISO are uniquely situated to consider the possible impacts of the technologies listed above on the State’s electric system reliability needs.

\textsuperscript{224} Outlook at 60.


14. Given that New York is not the only jurisdiction investigating options and opportunities for the research, development, and deployment of new technologies capable of achieving a zero emissions grid, how should the State seek to coordinate with and otherwise draw upon efforts that are underway elsewhere?

New York should actively coordinate with federal and other state agencies regarding research, development, and deployment of zero-emitting technologies—especially those that are eligible for financial support through federal government funding opportunities. As discussed with respect to hydrogen and CCS, the Commission must coordinate its program to meet the 2040 Zero Emissions Target with the EPA Proposed GHG Rule to provide certainty to generator owners that investments they make to comply with the rule will be recoverable in the NYISO’s competitive wholesale electricity market.

New York should consider the goals and targets of other states participating in the Regional Greenhouse Gas Initiative ("RGGI"), as well as neighboring non-RGGI states. New York should design a program that is compatible with other state programs, especially considering that the envisioned New York State Economywide Cap-and-Invest ("NYCI") program would use allowance auction proceeds for purposes such as the following: No less than 67% of the Climate Investment Account within the Climate Action Fund would be used to assist the State in transitioning to a less carbon-intensive economy—including, but not limited to, for the purposes of the Scoping Plan. The New York State program could eventually expand into a regional program, as is envisioned for the NYCI program.

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229 The 2023 enacted New York State Budget created the Climate Action Fund, which includes accounts such as the Climate Investment Account (Part TT of A.3006-C / S.4006-C – Chapter 56 of the Laws of 2023).
ISO New England (“ISO-NE”)\textsuperscript{230} and PJM Interconnection (“PJM”),\textsuperscript{231} New York’s neighboring independent system operators, may also have insight on the need for, and the scope and structure of, DEFRs.\textsuperscript{232} New York should collaborate with these ISOs to ensure that the reliability of the grids throughout the northeastern United States is always maintained.

\textsuperscript{230} About Us, ISO-NE, \url{https://www.iso-ne.com/about} (last visited Aug. 15, 2023).

\textsuperscript{231} About PJM, PJM, \url{https://www.pjm.com/about-pjm} (last visited Aug. 15, 2023).

\textsuperscript{232} Jennifer Runyon, ISO-NE: Significant Dispatchable Resources are a Must in a Decarbonized Grid, POWERGRID International (Aug. 3, 2022), \url{https://www.power-grid.com/der-grid-edge/iso-ne-significant-dispatchable-resources-are-necessary-in-a-future-decarbonized-grid/}. 

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IV. CONCLUSION

For the foregoing reasons, the Commission should designate as quickly as possible technologies that qualify as zero emissions sources for purposes of meeting the 2040 Zero Emissions Target. These technologies should include existing and advanced nuclear, long-duration storage, green/pink hydrogen and derivatives thereof, RNG and derivatives thereof, CCUS (including DAC), DERs (including VPPs and fuel cells), and demand response resources. The Commission should also establish a new tier under the CES to incent the deployment of the resources that it designates in this proceeding to help meet the 2040 Zero Emissions Target.

Dated: August 16, 2023
Albany, New York

Respectfully submitted,

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Exhibit 1 – Affidavit of David W. Cohn
NEW YORK STATE  
PUBLIC SERVICE COMMISSION

Case 15-E-0302 – Proceeding on Motion of the  
Commission to Implement a Large-Scale Renewable  
Program and Clean Energy Standard

AFFIDAVIT OF David W. Cohn

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AFFIDAVIT OF DAVID W. COHN

David W. Cohn, having been duly sworn, deposes and states as follows:

1. My name is David W. Cohn. I am employed as Vice President at Sargent & Lundy, LLC (“Sargent & Lundy”). My business address is 55 E. Monroe, Chicago, Illinois 60603.

2. My professional career has largely been devoted to matters relating to power generation. Included in my experience was the preparation of a study in 2006 for the California Public Utilities Commission describing alternatives to the Mojave Power Station that included an integrated gasification combined cycle power plant with carbon capture, as well as a study of the sequestration possibilities for that carbon dioxide (“CO₂”) stream. Included also was a study of the feasibility of carbon capture via shift reaction of the syngas fuel with concomitant conversion of the fuel to hydrogen for direct combustion. I have also conducted studies on small modular reactor (“SMR”) technology. My resume is attached as Exhibit A.

3. Sargent & Lundy is one of the longest-standing, full-service architect engineering firms in the world. Founded in 1891, the firm is a global leader in power and energy, with expertise in grid modernization, renewable energy, energy storage, nuclear power, fossil fuels, carbon capture, and hydrogen. A summary of Sargent & Lundy’s experience is attached as Exhibit B.

4. I have been asked by Independent Power Producers of New York, Inc. (“IPPNY”), to review the New York State Public Service Commission’s (“Commission”) Order Initiating
Process Regarding Zero Emissions Target, issued on May 18, 2023,\(^1\) in the above-captioned proceeding, and to provide my opinions and recommendations in response to the Commission’s exploration of the need for, and potential mechanisms required to incentivize the development of, electric generation technologies that are both zero greenhouse gas ("GHG") emitting and have the attributes that renewable facilities currently lack that are necessary to “support reliability once conventional fossil fuel generation has been removed from the system.”\(^2\)

**QUESTION 1 – ZERO EMISSIONS SOURCES**

**How should the term “zero emissions” as used under PSL 66-p(2)(b), be defined?**

5. On advice of counsel, in establishing the GHG emissions targets for the electricity sector (70% renewable by 2030, zero emitting electrical demand system by 2040), the Climate Leadership and Community Protection Act ("CLCPA") distinguishes between “renewable energy systems” and “zero emissions sources.”\(^3\) The CLCPA defines renewable energy systems, but, as the Commission recognized, it does not define zero emissions sources.\(^4\)

6. While the Commission defined renewable energy systems as zero emissions for purposes of meeting the 2030 and 2040 targets, the Commission’s exploration in this case is focused on non-renewable resources (those other than renewable energy systems).\(^5\) The Commission

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\(^1\) Case 15-E-0302, *Proceeding on Motion of the Commission to Implement a Large-Scale Renewable Program and a Clean Energy Standard*, Order Initiating Process Regarding Zero Emissions Target (May 18, 2023) ("May 18 Order").

\(^2\) May 18 Order at 11–12.

\(^3\) Chapter 106 of the Laws of 2019 (codified, in part, in Public Service Law ("PSL") § 66-p).

\(^4\) May 18 Order at 5.

\(^5\) May 18 Order at 14–15.
referenced studies (Brattle and New York Independent System Operator, Inc. (“NYISO”)) that call for up to 45 gigawatts (“GW”) of “backstop thermal” generation capacity and/or “dispatchable emission-free resources” to provide sustained on-demand power and system stability after 2040 that cannot be provided by, and are needed to complement, renewable resources alone. A dispatchable power source is one whose output to the grid can be controlled and reliably ramped up and down incrementally to meet changes in demand. A non-dispatchable source is a source of electricity that is intermittent and cannot be adjusted to meet fluctuating electricity demand. The Commission concluded that to achieve the CLCPA targets:

- additional policies, programs, or rules may be needed to address the issues that are expected to arise by 2040 or earlier when reliability requirements cannot be met by existing renewable generation and energy storage technologies alone, as well as to address other reliability challenges such as managing changing patterns of demand and maintaining the overall capabilities of the electric grid as the State integrates more intermittent resources.

Notably, given the CLCPA’s economy-wide scope, New York will face loads growing at an accelerated pace while more intermittent generation is being added to the system. However, as the Commission recognized, none of the referenced studies have explicitly identified what technologies need to be developed and deployed to provide the necessary system reliability. The Commission should identify technologies that can provide the needed generation capacity and dispatchable, emissions-free resources and provide the necessary incentives to

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7 May 18 Order at 14–15.
8 May 18 Order at 2.
ensure such technologies are built in a timely manner to meet the 2040 target. As I discuss in detail below, in response to the questions the Commission posed in its May 18 Order, examples of these resources include existing and advanced nuclear; SMRs; electrolytic hydrogen sourced from zero-carbon intensity electricity or any derivatives thereof; carbon capture and sequestration; renewable natural gas or any derivatives thereof; and long-term energy storage technologies.

7. “Net Zero” is the balance between GHG that is produced and the amount that is removed. “Net Zero is cutting [GHG] emissions to as close to zero as possible, with any remaining emissions re-absorbed from the atmosphere, by oceans and forests for instance.”9 Zero emissions sources can therefore be defined as systems, other than renewable energy systems, that can individually, or in combination, deliver net zero GHG equivalent electricity. A technology that produces *de minimis* emissions in relation to the technology’s total emissions should also qualify as a zero emissions resource to include the broadest level of technologies that can meet reliability needs and reduce GHGs from the electricity sector as near to zero as possible.

**QUESTION 2 – ZERO GHG EMISSIONS SOURCES**

Should the term “zero emissions” be construed to include some or all of the following types of resources, such as advanced nuclear (Gen III+ or Gen IV), long-duration storage, green hydrogen, renewable natural gas, carbon capture and sequestration, virtual power plants, distributed energy resources, or demand response resources? What other resource types should be included?

8. The term zero emissions should include all of the resources identified above, the additional resources as discussed below, and the resources in the responses to Question 3 for existing

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and advanced nuclear, Question 6 for long-term storage, and Question 4 for virtual power plants (“VPP”).

**Green/Pink Hydrogen**

9. Green hydrogen is hydrogen produced by electrolysis using electricity that has been produced without the emission of GHGs. Pink hydrogen refers to hydrogen that is produced by electrolysis powered by nuclear energy. Hydrogen generated from carbon-free processes can ultimately be used as fuel to power dispatchable emissions-free resources. However, investments to establish a robust hydrogen storage and transportation infrastructure must be made (see discussion on green ammonia below as a potential for storage and transportation). Combustion of elemental hydrogen involves only hydrogen and does not involve carbon, so no GHGs are formed during that combustion. Nitrogen oxides (“NOx”) are controlled using long-established, widely used technologies, such as selective catalytic reduction (“SCR”).

10. Conveyance of hydrogen is viable. However, widespread distribution presents technical and commercial challenges and will require costs to be incurred to retrofit facilities. Hydrogen has been transported by pipeline since 1938, and about 1,600 miles of pipeline are in operation in the United States, 1,200 miles in Europe, and 125 miles in South Korea. Pipeline construction for hydrogen is regulated by the standard ASME B31.12, Hydrogen Piping and Pipelines.\(^\text{10}\) Hydrogen gas blended up to about 20% with natural gas could use existing natural gas pipelines without significant change. For a blend higher than 20% hydrogen, repurposing existing natural gas pipelines will be required to meet technical challenges depending on the type of pipeline and operational characteristics. Technical

\(^{10}\) *Energy Technology Perspectives 2023*, International Energy Agency (Jan. 12, 2023) at 311, available at https://iea.blob.core.windows.net/assets/a86b480e-2b03-4e25-bae1-da1395e0b620/EnergyTechnologyPerspectives2023.pdf.
challenges for blending hydrogen up to 100% through new or existing pipelines include fatigue, crack growth, and fracture resistance of the piping systems, operating pressure, leakage, and safety. Older gas lines will need to be inspected to evaluate if they can be modified for hydrogen. Technical evaluation includes age and type of manufactured pipe, number of latent defects, operating conditions, valves, and compressor stations.

11. Hydrogen leakage is a significant design concern for any type of hydrogen infrastructure. Valve station leakage can be minimized by repairing or replacing valves (valve stations are located typically every 5 to 20 miles) and regularly inspecting the gas line. Internal inspection is done using devices (known as “pigs”) that travel inside the pipeline. Gas companies inspect gas lines for leakage, including leak and seat tests of valves. Inspection for leakage can be done with flame ionization, which is suitable for low concentrations of hydrogen. In May 2023, the United States Department of Transportation (“DOT”) proposed a new rule to significantly improve the detection and repair of leaks from existing pipelines.11 The Commission and the New York State Department of Environmental Conservation (“DEC”) also have jurisdiction and exiting rules and programs.

12. On May 23, 2023, New York State Governor Kathy Hochul announced a $10 million initiative to advance innovative clean hydrogen research, development, and demonstration projects that address the challenge of replacing fossil fuel usage in hard-to-electrify

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sectors. This solicitation is open to fund projects proposed by New York-based entities that are also actively applying for federal clean hydrogen funding opportunities supporting the CLCPA goals to reduce emissions 85% by 2050 and transition to 100% zero-emission electricity by 2040.

13. European countries have conducted numerous studies and demonstrations of hydrogen blending in existing gas transmission lines, and the United States has successfully commissioned several blending projects. Hawai’i Gas, the state’s only franchised gas utility, has approximately 50 years of experience on this front, blending 12% to 15% of hydrogen with natural gas into its network since the 1970s. The New York Power Authority (“NYPA”) partnered with the Electric Power Research Institute (“EPRI”), General Electric Co. (“GE”), Airgas, Sargent & Lundy, and Fresh Meadow Power, LLC to develop the effectiveness of generating power using up to 40% hydrogen at its Brentwood Power Station on Long Island without any modifications to the gas turbine. The project began in the fall of 2021, with testing completed during the third quarter of 2022. In total, the project burned blended hydrogen for a total of 12.5 hours at varying load ranges showing a decrease in CO₂ emissions of as much as 20% at peak hydrogen levels.

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14. National Grid plc (“National Grid”) and the Institute of Gas Innovation and Technology (“I-GIT”) at Stony Brook University are working on a research and development (“R&D”) plan to evaluate increasing levels of hydrogen blending in gas networks and how hydrogen can be blended in. The New York State Energy Research & Development Authority (“NYSERDA”) awarded funding in late 2020 for I-GIT and Brookhaven National Laboratory to test pipe samples removed from actual gas services, expose them to hydrogen, and test for strength and stability. Additionally, the National Renewable Energy Laboratory (“NREL”) with participants including six other national laboratories, I-GIT, the Gas Technology Institute, and the National Grid is performing R&D and evaluation of the potential impact of hydrogen blending into existing gas infrastructure. The $12.65 million project began in August 2021 with a two-year timeframe.

15. If site geologic conditions are favorable, electrolytic hydrogen can be generated using nuclear power or intermittent renewable energy and stored on-site for use in dispatchable generation when needed, using technologies designed for hydrogen fuel. Such a concept is planned as part of the Advanced Clean Energy Storage project in Delta, Utah, where solution mined salt caverns will store up to 300 gigawatt hours (“GWh”) of energy.

16 Id.

17 Id.

16. In a study released in 2023, the National Energy Technology Laboratory (“NETL”), the Pacific Northwest National Laboratory, and the Lawrence Livermore National Laboratory demonstrated that existing United States underground gas storage can store hydrogen-methane blends.\(^\text{19}\) Hydrogen storage in existing underground gas storage facilities can sufficiently buffer the hydrogen demand projected for 2050.\(^\text{20}\) Total working natural gas storage underground capacity in the United States is 4,797,892 million cubic feet (“MMcf”).\(^\text{21}\) New York’s working natural gas underground natural capacity is 125,099 MMcf as of May 2023.\(^\text{22}\)

17. There are currently three demonstration hydrogen projects at nuclear plants, one of which is in upstate New York and has formed the basis for the State to avail itself of additional development opportunities through research programs:\(^\text{23}\)

- A low-temperature electrolysis system at Nine Mile Point Nuclear Station (“Nine Mile Point”) in Oswego, New York, began generating hydrogen in February 2023. The owner and operator of Nine Mile Point, Constellation Energy Corporation (“Constellation”), has also partnered with NYSERDA to power a fuel cell scheduled to provide power to the grid in 2025.

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\(^{20}\) \textit{Id.}

\(^{21}\) \textit{Underground Natural Gas Storage Capacity}, U.S. Energy Information Administration (July 31, 2023), \url{https://www.eia.gov/dnav/ng/ng_stor_cap_a_EPG0_SACW0_Mmcfe_m.htm}.

\(^{22}\) \textit{Id.}

• A low-temperature electrolysis system at the Davis-Besse Nuclear Power Station, Unit 1, located in Oak Harbor, Ohio, is scheduled to produce hydrogen by 2023.

• A high-temperature electrolysis demonstration project at the Prairie Island Nuclear Generating Plant, Unit 1, located in Red Wing, Minnesota, is scheduled to produce hydrogen in 2024.

18. Generators combusting hydrogen can be used as a dispatchable source to maintain grid reliability as a complement to periods when renewable facilities and battery storage cannot meet electric demand—especially during peak conditions, which will be worse during extreme weather events. As the NY Renews Policy Committee has stated: “If produced by carbon-free means and used for limited but essential energy purposes, hydrogen can be valuable in the energy mix of a decarbonizing economy.”

19. Electricity generation from hydrogen is a commercially viable technology today.

Combustion turbines (“CTs”) have been burning fuel with varying amounts of hydrogen for decades. As an example, Mitsubishi Power, Ltd. (“Mitsubishi”) has fired 29 gas turbine units with hydrogen content ranging between 30% and 90%—with more than 3.5 million operating hours since 1970. GE’s fleet has more than 100 smaller gas turbines (Frame 5 and 6B.03) that have, or continue to operate on, fuels that contain hydrogen, including 30 gas turbines that have operated with at least 50% (by volume) hydrogen with over 2.5 million operating hours. GE has developed a technology roadmap to achieve 100%.

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hydrogen in the next decade.\textsuperscript{27} Siemens Energy is working toward a full fleet of 100% hydrogen industrial gas turbines by 2030.\textsuperscript{28} Mitsubishi is working on a new multi-cluster turbine combustor that is projected to be completed by 2024. Many smaller original equipment manufacturers ("OEMs") have plans for 100% hydrogen turbines in the coming years as well. Kawasaki Heavy Industries Ltd. tested a 100% hydrogen capable turbine in 2019 with a dry low NO\textsubscript{x} ("DLN") combustor design.\textsuperscript{29} Nearly all major OEMs of combustion turbines have some capability with 100% hydrogen combustion in their current equipment, with the goal of expanding these capabilities fleet wide in the coming years.

20. The path to firing 100% hydrogen will be accomplished in steps. Currently, a hydrogen fuel mix of 20% can be used in existing gas turbines. The characteristics of hydrogen result in combustion flashbacks when mixing hydrogen with air. Flashback is when the flame is not able to stabilize and is pushed back into the fuel-air mixing zone, which can lead to combustor and fuel nozzle damage. Turbine manufacturers are working on new combustors and fuel nozzles for heavy frame gas turbines toward 50% and higher hydrogen content using current technology of premix (DLN) combustion, in which fuel and air are mixed prior to going into the combustor, which has a lower NO\textsubscript{x} emission. To attain a 50%


\textsuperscript{29} \textit{World's First Successful Technology Verification of 100% Hydrogen-fueled Gas Turbine Operation with Dry Low NO\textsubscript{x} Combustion Technology Improving Power Generation Performances to Realize a Hydrogen Society}, Kawasaki Heavy Industries, Ltd. (July 21, 2020), https://global.kawasaki.com/news_200721-1e.pdf.
reduction in CO$_2$ emissions, fuel requires a blend of 50% hydrogen and 50% methane.\textsuperscript{30} Mitsubishi stated that it has successfully applied 100% hydrogen using a “diffusion technology,” during which fuel and air are put in the combustor separately, but results in a high NO$_x$ emission.\textsuperscript{31} GE stated that it has successfully demonstrated burning hydrogen up to 90% in its Multi-Nozzle Quiet Combustor (“MNQC”) combustion system. GE indicated that it “is able to quote hydrogen levels up to 90 to 100% for applications with the MNQC or single nozzle combustor.”\textsuperscript{32}

21. To accomplish effective hydrogen operations, significant additional retrofit costs will be incurred. Existing gas turbines may require upgrading equipment and design to a combustor and fuel nozzles configured for operation on hydrogen. Upgrades to limit NO$_x$ emissions will also be required through pre- or post-control technology, such as water injection or SCR. In addition to the combustion section upgrades, retrofits to other plant components and procedures will likely be required, including:

- Fuel piping size changes
- Fuel piping system flanged joint replaced with welded joints
- Gas turbine control upgrades
- Continuous emission monitor system modifications/upgrades
- Safety sensors and leakage detectors
- SCR modifications


\textsuperscript{31} \textit{Hydrogen – The Key to Achieving Carbon Neutral by 2050}, Mitsubishi Heavy Industries Group (last visited Aug. 11, 2023), \url{https://solutions.mhi.com/power/case-studies/hydrogen-the-key-to-achieving-carbon-neutral-by-2050/}.

\textsuperscript{32} GE Hydrogen Whitepaper at 9.
• Upgrades to the fire detection and fire protection system and exclusion zones for handling hydrogen

22. Chemical combustion of hydrogen involves a reaction with oxygen in the air supply to form water as the only byproduct. However, due to the high temperature of the combustion process, nitrogen in the air also reacts with oxygen to form NO\textsubscript{x} through a secondary reaction. NO\textsubscript{x} emissions have been effectively managed in power production applications for several decades to meet federal, State, and local requirements on emissions. New and existing applications that will address emissions in accordance with environmental regulations can be required to determine the best available control technology (“BACT”) to control these emissions.\textsuperscript{33} For NO\textsubscript{x} emissions control, BACT commonly includes dry low emissions combustors, combustion dilution, and post-combustion mitigation such as SCR.

23. Most combustion turbine OEMs are working on advanced combustor technologies to keep NO\textsubscript{x} emissions low with high hydrogen contents in the fuel up to 100% hydrogen.\textsuperscript{34} Other means of managing NO\textsubscript{x} emissions include equipment such as SCR and selective non-catalytic reduction units. These units use chemical reactions downstream of the combustion process to convert NO\textsubscript{x} compounds into molecular nitrogen and water vapor. SCR is the primary technology being used at current natural gas fuel electric generators to reduce NO\textsubscript{x} below thresholds established by the United States Environmental Protection Agency (“EPA”) and DEC. SCR has been regularly employed in gas turbine systems to control NO\textsubscript{x}


concentrations below 2 parts per million (“ppm”). In South Korea, a 45 MW gas turbine at a refinery has been operating on gases up to 95% hydrogen for 25 years. All major gas turbine and reciprocating gas engine manufacturers are actively developing technology to fire up to 100% hydrogen. Firing 100% hydrogen with DLN technology has been demonstrated at 1 MW scale.35

24. In May 2022, a hydrogen blending test was performed at Constellation’s Hillabee Generating Station, a 753 MW combined cycle power plant, with a 38% blend of hydrogen with no increase in NOx emissions.36

25. The United States Department of Energy’s (“DOE”) Energy Earthshots initiative is designed to accelerate breakthroughs of more abundant, affordable, and reliable clean energy.37 The DOE Hydrogen Shot establishes a framework and foundation for clean hydrogen with the goal to reduce the cost of clean hydrogen in one decade from the current level of approximately $5 per kilogram, down to $1 per kilogram.38

26. Hydrogen demand was 94 million tonnes (“Mt”) in 2021, which is approximately 2.5% of global energy consumption. The International Energy Agency (“IEA”) estimates that


hydrogen demand could reach 115 Mt in 2030.\textsuperscript{39} This compares with the 130 Mt needed to meet existing climate pledges worldwide, and 200 Mt in 2030 to be on track for net zero emissions by 2050.

**Green/Pink Hydrogen Derivatives**

27. Ammonia can serve as a hydrogen and energy carrier. Ships, ports, storage, and infrastructure are all in place. About 20 million tons of ammonia are transported by sea each year.\textsuperscript{40} Ammonia is widely used to make agricultural fertilizers. It requires less energy to liquify and transport and has a higher volumetric energy density than liquid hydrogen. After the ammonia is shipped, it can be converted back into hydrogen and nitrogen. Ammonia is synthesized from electrolytic hydrogen and nitrogen produced from an air separation unit, all powered from electricity produced without emission of GHGs. The direct use of ammonia has been successfully demonstrated in micro gas turbines (50 kilowatts ("kW")). Mitsubishi announced plans to commercialize a 40 MW gas turbine combusting 100% ammonia by 2025.\textsuperscript{41} NO\textsubscript{x} is controlled using long-established and widely used SCR systems.

**Renewable Natural Gas and Derivatives**

28. Renewable natural gas ("RNG") is biogas (45% to 60% methane) that has been upgraded for use in place of fossil natural gas (methylene content of 90% or greater). The biogas used to


produce RNG comes from a variety of sources, including municipal solid waste landfills, digesters at water recovery facilities, livestock farms, food production facilities, and organic waste operations. If not captured, biogas collected to produce RNG eliminates the release of the potent GHG, methane, into the atmosphere. Treatment of raw biogas to RNG includes removing moisture, CO₂, and trace level contaminants along with reducing the nitrogen and oxygen content to reach a methane content of 96% to 98%. Methane’s climate impact is far greater than CO₂, so the alternative combustion of renewable natural gas results in lower GHG emissions. On a net basis, the GHGs are less than zero, based on methane’s impact being greater than CO₂. Further, methane is more than 25 times as potent as CO₂ at trapping heat in the atmosphere. The EPA’s Landfill Methane Outreach Program and its AgSTAR Program work with various industries to avoid methane emissions by supporting biogas energy projects—including those that produce RNG. RNG can be used as a dispatchable source for gas-fired electric generating plants to maintain grid reliability when renewables and battery storage do not meet electric demand.

29. Renewable diesel and other biofuels can be produced from nearly any biomass feedstock through a variety of processes, including hydrotreating, gasification, pyrolysis, and other biochemical and thermochemical technologies. Biodiesel is produced from vegetable oil (mainly soybean oil). Biofuel production in 2022 was 2,509 trillion British thermal units (“Btu”), which was 20% of the total renewable energy production of 13,289 trillion Btu.¹⁴² In January 2023, Renewable diesel consumption (0.144 million barrels per day) surpassed

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biodiesel consumption (0.109 million barrels per day). Biodiesel is blended with petroleum diesel for use in diesel engines. Renewable diesel is fully refined and cracked using petroleum refining technology. Methanol is an emerging biofuel that can be used for turbine engines that are used as “peak generators” to maintain grid reliability. Power plants operating on diesel can be converted to operate on methanol. Israel Electric Corporation converted a 50 MW Pratt & Whitney turbine at a power plant in 2014 at the Eilat generating station to operate on methanol. Production of renewable methanol has been demonstrated by Enerkem which has operated a full-scale commercial plant in Edmonton Canada since 2016 producing about 1.3 million gallons of renewable methanol.

30. Renewable propane (also called bio propane) is made from a variety of feedstocks, which are the same byproducts used to create biofuels. The most common feedstock today is a byproduct (which if not used would be resigned to a landfill) of renewable diesel and sustainable aviation fuel made from plant and vegetable oils, animal fats, or used cooking oil. According to data from the EPA, 4.6 million gallons of renewable propane were produced in 2021.

31. There are 230 operational RNG projects in the United States (13 food waste, 76 landfill, 115 livestock/agriculture, and 26 water resource recovery facilities). This includes 11 projects in

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New York (1 landfill, 9 livestock/agriculture, and 1 water resource recovery facility).\textsuperscript{47}

Please see paragraph 71, in the response to Question 8-Renewable Natural Gas, for additional information on RNG.

**Demand Response Resources**

32. Demand response resources can help reduce the need to utilize non-zero emission sources to meet load demand. Demand response reduces or shifts consumer usage during peak periods in response to financial incentives (like time-based rates). With increased renewable generation, dispatch is a “duck curve” (starting high in the morning, dropping off mid-day, increasing in the evening, and then dropping off at night).\textsuperscript{48} Incentives for consumers to switch usage to lower usage periods (e.g., charging electric vehicles in the evening, doing laundry in the afternoon or night, etc.) can reduce demand during peak periods and provide a valuable zero emissions dispatchable resource.

**Carbon Capture and Sequestration**

33. A natural gas combined cycle generating facility utilizing carbon capture and sequestration (“CCS”) can be a net zero generation source. CCS captures the CO\textsubscript{2} before emissions enter the atmosphere. CCS is not considered an emerging technology because it has been in operation for decades, including in the electricity generation sector. However, because utility-scale CCS is expected to remove 95\% to 98\% of the CO\textsubscript{2}, it should be considered a zero emissions source because the remaining CO\textsubscript{2} emissions are \textit{de minimis} or they can be matched up with other negative emission technologies, such as RNG or direct air capture


\textsuperscript{48} See additional discussion of the duck curve in paragraph 43, \textit{infra}. 
and storage of GHGs. Conventional emissions, such as NOx, can be controlled using conventional control technologies.

34. Carbon capture, use, transport, and storage is a proven, decades-old process. To date, a total of more than a quarter of a billion tons of CO₂ has been captured and stored globally, and more than a gigaton (“Gt”) of CO₂ has been transported for use or storage.49

35. Globally, in 2022, 46 million metric tons of CO₂ was captured and geologically stored from a wide range of industries, including natural gas processing, ethanol, hydrogen, fertilizer, chemicals, and power generation. By 2030, carbon capture projects are predicted to capture and store 254 million metric tons of CO₂ per year globally.50

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<th>Carbon Capture and Storage Projects Operating</th>
<th>Carbon Capture and Storage Projects in Development</th>
<th>2022 Carbon Capture Capacity (million metric tons of CO₂ per year)</th>
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<td>United States</td>
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Source: Global CCS Institute, Global Status of CCS 2022

QUESTION 3 – NUCLEAR ENERGY TECHNOLOGY

How should a program to achieve the Zero-Emission by 2040 Target address existing and newly constructed energy resources. Should the program be limited to specific types of nuclear energy technologies and exclude others?

36. Nuclear energy is a zero-emission clean energy source. In 2022, 21% of electricity in New York was generated by nuclear facilities.51 Nineteen percent of the electricity in the United States was generated by nuclear facilities.


50 Id.

States is generated by nuclear facilities,\textsuperscript{52} and according to the Nuclear Energy Institute (“NEI”), the United States avoided more than 476.5 million tons of CO\textsubscript{2} emission in 2021.\textsuperscript{53} Nuclear power amounts to 413 GW of capacity across 32 countries, contributing to avoiding 1.5 Gt of global emissions and 180 billion cubic meters of global gas.\textsuperscript{54} Nuclear power is the second largest source of low emissions power after hydropower.

37. Nuclear generation emits no GHGs during operation. Chemical combustion does not occur in the generation technology during the production of energy, so neither CO\textsubscript{2} nor other GHGs are formed or released. Existing nuclear generating facilities are primarily operated at baseload due to their relatively low marginal costs and structure to maintain a consistent operating level based on their current design and operation. In 2020, electricity produced by nuclear had an average capacity factor of 92.7%. Currently, four nuclear plants are operating in New York with nameplate summer capacity of 3,304 MW.\textsuperscript{55} In 2022, the State’s nuclear plants generated 26,883 gigawatt hours (“GWh”).\textsuperscript{56}

38. The energy content of nuclear fuel represented by one uranium pellet (about 1 inch tall) equals 17,000 cu/ft. of natural gas and 120 tons of oil. Used nuclear waste fuel produced over the past 70 years could fit on a football field at a depth of less than 10 yards.\textsuperscript{57} The


\textsuperscript{54}Nuclear Power and Secure Energy Transitions, International Energy Agency (June 2022), at 1, https://iea.blob.core.windows.net/assets/016228e1-42bd-4ca7-bad9-a227c4a40b04/NuclearPowerandSecureEnergyTransitions.pdf.

\textsuperscript{55}NYISO 2023 Gold Book at 73, 82–83.

\textsuperscript{56}Id. at 75.

Nuclear Waste Policy Act of 1982 supports the use of deep geological repositories for safe storage and/or disposal of radioactive waste. Construction of Yucca Mountain Nuclear Waste Repository was halted, and nuclear facilities currently safely store spent fuel on site through systems that incorporate pools or dry casks.

39. Nuclear and fossil-fueled power plants use circulating water to cool the steam coming out of the turbine and condense it back into water, which is then recycled back through the system. Three methods of cooling include direct once-through cooling, recirculation cooling, and dry cooling. Most plants have recirculation cooling using a cooling tower. The cooled water from the condensation of steam is then returned to the condenser. Circulating water lost to evaporation at the cooling tower is water consumed by the power plant but not lost because water vapor reenters the water system through rainfall. Water usage from a nuclear plant is about 825 MWh compared to 210 MWh for a combined cycle plant. Dry cooling using large cooling fans reduces water usage by about 90% but decreases plant efficiency by 5% to 10%. The NuScale SMR design at Utah Associated Municipal Power Systems’ (“UAMPS”) Carbon Free Power Project utilizes dry cooling.

40. With the increase in renewable energy, there is ongoing work on implementing or improving nuclear plants to be more flexible to follow load, including daily variations of demand. Existing nuclear plants may be able to provide flexible operation depending on

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their design and associated regulations. The International Atomic Energy Agency reported that France has designed or converted many of its nuclear plants for flexible operation.60

41. New nuclear plants are being designed to provide more flexible operation. SMRs, in comparison to existing nuclear plants, are generally simpler, smaller (approximately 60 MW to 300 MW), provide more flexible operation, and the safety system relies on more passive systems. Several SMRs at one site provide flexibility to provide power as needed.

42. UAMPS teamed with NuScale and Energy Northwest to construct a 720 MWe NuScale power plant at the DOE’s Idaho National Laboratory with the “flexibility to ramp up and down as needed to follow load and complement intermittent renewable supply.”61 Construction of UAMPS’ Carbon Free Power Project is expected to begin in December 2025 with the first power module in operation by 2029.62

GE Hitachi Nuclear Energy stated that it is working to deploy three additional BWRX-300 SMRs at the Darlington New Nuclear Project site in Ontario, Canada.63 As the Commission recognized in its Order Adopting a Clean Energy Standard,64 nuclear generation plays an important role in helping the State achieve its clean energy targets. With New York and other states implementing public policy initiatives designed to significantly reduce their


63 Darrell Proctor, Three More BWRX-300 SMRs Planned for Canada’s Darlington Site, POWER (July 7, 2023), https://www.powermag.com/three-more-bwrx-300-smrplanned-for-canadas-darlington-site/.

carbon emissions, nuclear facilities provide a reliable, base-loaded, source of large amounts of zero-emission electricity. Policy mechanisms to preserve New York’s existing generation fleet and incentivize new nuclear technologies should be considered to achieve GHG emissions targets from the electric sector.

**QUESTION 4 – NEED FOR BROADER SET OF TECHNOLOGIES**

Should new measures adopted to pursue compliance with the Zero-Emission by 2040 Target focus exclusively on generation and resource adequacy, or should they also encompass a broader set of technologies that could be integrated into the transmission or distribution system segments, or installed and operated behind-the-meter?

43. Compliance with the 2040 target will require a broader set of technologies to provide reliability. Grid stability is currently provided with dispatch control of large thermal plant rotating synchronous generators. As they are retired or taken out of service, grid stability must be accomplished with control of considerably more types of sources through communication with dispatch control. Behind-the-meter technologies, such as the 10 GW of distributed solar (2030) will require the means to balance the supply and demand on the grid due to the increased need of generation when the sun sets and contribution from solar drops rapidly (duck curve). The duck curve shows the difference in electricity demand and amount of available solar energy during the day. It was first documented by the California Independent System Operator in 2013 and is commonplace in the conversion to large scale solar photovoltaic (“PV”). The net demand is in the early morning and evening when generation from solar is not available. System integration will be required and is being studied by the DOE Solar Energy Technologies Office to help grid operators manage the challenges of the duck curve from extreme swings when variable renewable generation drops off.
44. Dynamic Line Ratings change the amount of current that can flow through an electric transmission line in response to real time weather conditions and allow grid operators to manage congestion and increase grid resilience and reliability as renewable penetration increases.65

45. VPPs are generally defined as an aggregation of distributed energy resources (“DERs”) equipped with “smart” inverters such that their utilization can be coordinated by a centralized control and communications system. The resources themselves are typically comprised of residential or commercial rooftop solar PV and lithium-ion battery energy storage systems (“BESS”) but may also include any number of “smart” devices like electric vehicle chargers, thermostats, and smart laundry machines that are equipped with the necessary communications technologies to enable remote control. Many of the grid services VPPs are designed to deliver will also yield carbon emission-reduction benefits as a corollary benefit.

- Demand Response Optimization: VPPs can be used to facilitate demand response programs, where electricity consumers can adjust their energy usage patterns, or, in some cases, their connected loads can be remotely controlled, in response to price signals or grid conditions. By optimizing demand response within a VPP, the overall energy demand can be better balanced with the available renewable energy supply. This helps to reduce the need for conventional fossil fueled power plants that contribute to carbon emissions during peak demand periods.

- Energy Storage Management: VPPs incorporate energy storage systems, such as BESS or electric vehicles with bi-directional inverters, to store excess energy during times of high renewable energy generation. This stored energy can be dispatched during periods of high demand or low renewable energy availability. By intelligently managing the

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charging and discharging of energy storage systems, VPPs can enhance grid stability, minimize curtailment of renewable energy, and reduce the need for carbon-intensive backup power sources.

- **Grid Flexibility and Ancillary Services:** VPPs can provide grid flexibility by dynamically adjusting the power output of DERs based on grid conditions and system requirements. This flexibility enables the integration of intermittent renewable energy sources into the grid and supports grid stability. Additionally, VPPs can offer ancillary services, such as frequency regulation and voltage.

**QUESTION 5 – SUBCATEGORIES OF ENERGY RESOURCES BASED ON PARTICULAR CHARACTERISTICS**

Should any program to achieve the Zero-Emission by 2040 Target specify subcategories of energy resources based on particular characteristics, such as ramp rates, the duration of their operational availability, or their emissions profile with respect to local pollutants?

46. It is important for grid system reliability to:
   1) Match generation supply with electricity demand;
   2) Follow the changes in demand with changes in supply;
   3) Provide reactive power support to match the overall difference in phase between electrical system voltage and current;
   4) Support maintenance of system frequency; and
   5) Support maintenance of system voltages.

47. Because renewable energy systems have low levels of ability to provide these services, due to their intermittent nature, other systems are required to complement renewable operations and provide these services. Battery energy storage systems can be used to help match supply and demand and follow changes in demand. Currently, reactive power, frequency, and voltage support are provided by rotating synchronous machines connected to the electric system. These include some renewables like hydropower, geothermal, and in some cases,
wind generators. These provide inertia to counteract changes in voltage and frequency. They are usually equipped with excitation systems that can be adjusted to meet electrical system reactive power requirements. Battery-inverter systems can also be provided with controls to compensate frequency variations and to provide voltage and reactive support.

48. Another possibility to supply needed inertia and reactive power is to use the synchronous generators of existing thermal facilities that will be decommissioned as “synchronous condensers.” Synchronous condensers are formed by uncoupling the generators from their prime movers, starting them as synchronous motors by any appropriate means (such as Load Commutated Inverter), and synchronizing them. These devices can provide reactive power control to the electric system, and their rotating mass can continue to provide inertia to the electric system which can be used to dampen transient fluctuations in frequency and voltage.

49. The above-described attributes could be incentivized through dedicated tiers incorporated within the CES program or other potential incentive programs or mechanisms to ensure that the needed electric reliability can be maintained as system supply shifts to rely more extensively on renewable generation sources.

QUESTION 6 – TECHNOLOGY INNOVATION

What role does technology innovation need to play to meet the CLCPA’s Zero-Emission by 2040 Target?

50. Dispatchable emission-free resources ("DEFRs") must be developed for commercial deployment. As reported by the NYISO, DEFRs will be essential in maintaining a reliable electric grid but are not commercially available today.66

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51. The higher integration of intermittent renewable energy will increase the need for more flexibility and energy storage. Lithium-ion (“Li-ion”) batteries are being deployed, but, with the extensive expansion, there are potential supply issues of availability of lithium and other materials.

52. Additional storage technologies should be considered such as molten salt, compressed air, flywheels, and tidal energy.

53. Molten salt can store heat, and electricity can be generated from the stored heat ranging from 8 to 24 hours. Heat energy from the grid, nearby power plants, or heat pumps provide the energy to store heat. Boston, Massachusetts, based company Malta Inc. has developed a concept for a 100 MW, stand-alone molten salt storage energy storage system using electricity from the grid and heat pumps, and has an agreement with Orlando Utilities Commission to develop the project.

54. Flywheels powered by electricity can store electrical energy as rotating inertia. Flywheels are limited to short-term applications such as spinning reserve for grid frequency.

- The world’s largest flywheel, installed in 2022 in Ireland’s Moneypoint Power Station, has a mass of 130 tons and can rotate up to 3000 rpm.

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- A storage project in the Netherlands in 2022 combined a 10 MW battery with a 3 MW flywheel to maintain grid frequency.\textsuperscript{70}

55. Compressed air storage (“CAES”) technology compresses and stores air under pressure in underground caverns or special above ground containers. Electricity is converted into thermal and mechanical energy as hot compressed air.\textsuperscript{71}

56. In diabatic CAES plants, the heat generated is removed by coolers. The air is then heated during the expansion phase in a gas turbine generator to produce electricity. Two diabatic CAES plants have been in operation: Germany (Huntorf, 1978, 290 MW and retrofitted to 320 MW) and the United States (McIntosh-Alabama, 1991, 110 MW/2.86 GWh).\textsuperscript{72}

57. In adiabatic CAES plants, the heat generated during the gas compression stage is stored and used to heat the compressed gas during the expansion phase. Hydrostor Inc. is planning to build two plants in California (each with capacity of 500 MW/4 GWh) and one plant in Australia with capacity of 200 MW/1.6 GWh.\textsuperscript{73}

58. Li-ion batteries are broadly deployed for many power applications and use is rapidly growing. Li-ion batteries currently are used for short durations (4 to 6 hours). Challenges in developing Li-ion batteries include limited supply chain, manufacturing, and safety.\textsuperscript{74}


\textsuperscript{72} \textit{Id.}

\textsuperscript{73} \textit{Id.}

• Limited supply chain: the U.S. does not currently produce lithium. The United States does not have a large reserve of cobalt, which is also used for Li-ion batteries. A domestic supply through recycling will be needed to mitigate the supply risk.

• Manufacturing: new approaches to component design are needed to increase energy density and reduce costs.

59. Li-ion technology was used in 90% of the installed large-scale battery storage operating in the United States in 2019. Lithium supply for large-scale batteries will be in competition with electric vehicles. The NYISO baseline projection is 85% of light vehicle sales will be electric (about 6 million electric vehicles on the road in 2040). Most key minerals are mined in Australia, Chile, and the Democratic Republic of the Congo. China produces 75% of all Li-ion batteries and more than half of the lithium, cobalt, and graphite processing and refining used in batteries are located in China.

60. Li-ion batteries are known to experience thermal runaway under certain circumstances. Research is required for the most economic and safe approach to manufacturing and integrating batteries.

61. There is ongoing research and development for alternative lithium-free battery technologies. Sodium-based battery storage was used in 4% of the installed battery storage in 2019. Sodium is an established technology with abundant material and requires a high operating temperature (about 572°F) using molten salt for large-scale battery storage. Sodium-ion

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76 NYISO 2023 Gold Book at 15.


battery technology (not molten salt) is being used for urban electrical vehicles with lower range, mainly in China (approximately 6% of China’s battery capacity), with plans to expand production.\(^79\)

62. Flow batteries use a liquid solution to store energy. Flow batteries are less sensitive to deep discharge, have a longer life cycle, and unlimited energy capacity. Flow batteries will be needed to provide alternative technology that is not dependent on lithium and is more suitable for larger energy-to-power requirements. Challenges in developing flow batteries include manufacturing technologies, standard supply chain, and scale-up. Flow batteries were used in 1% of the large-scale batteries installed in the United States in 2019.\(^80\)

- **Manufacturing technologies:** components are expensive and will need additional research to optimize manufacturing and lower cost.
- **Supply chain:** the current technology relies on vanadium, which is mostly imported. Vanadium supply is limited, and less expensive alternatives are being investigated.
- **Scale-up:** the manufacturing process will need to be developed to support larger deployments.

63. Tidal energy harnesses the flow of ocean current and tides to generate electricity. Technologies are nearing commercialization. The range of tidal technology ranges from 0.1 MW to 2 MW.\(^81\) Since 2010, more than 26.8 MW of tidal technology has been developed in Europe with 11.9 MW currently in operation (14.9 MW decommissioned).\(^82\)

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\(^82\) *Id.*
64. Fuel cells convert hydrogen to electricity and heat producing only water and no direct emissions. Fuel cells can achieve efficiencies over 60% (and greater than 80% if heat output is included). Research is needed to drive innovation and thus reduce the current cost of producing hydrogen and fuel cells.

QUESTION 7 – LIFE CYCLE ANALYSIS

Should life cycle emissions impacts be considered when characterizing energy resources? If so, how?

65. Life cycle analysis (“LCA”) is a method used to evaluate the environmental impact of a product (typically the equivalent greenhouse gas emissions) through its life cycle, encompassing extraction and processing of the raw materials, manufacturing, distribution, use, recycling, and final disposal. Historically, LCAs have been more focused on products rather than looking at the impact of an overall project or electrical resource.

66. Developing an LCA for a project or particular electrical resource is much more complex than estimating LCA for a manufactured product because it requires aggregation of many different materials and processes into one project. For example, one can estimate an LCA for cement used at a facility, but the estimate must include consideration of the source of that cement, the LCA associated with the production of that cement, and the LCA for the transportation of that cement to the facility. The same estimates would have to be made for all the other raw materials, equipment, and components to arrive at an estimate for an entire generation facility.

67. There are many ways to perform a LCA depending on the project and application. These can be completed using a range of programs (such as OpenLCA, GREET, and SimaPro) as well as direct calculation. For each of these processes, a very large number of inputs need
to be defined, and the level of detail and source of that input can vary widely for each technology considered and for each project.

68. For example, with OpenLCA, which is the program developed by NETL suggested for DOE funded CCS projects, the products must be inputted. These product inputs can be sourced from a database of product systems (https://nexus.openlca.org/), all of which have a wide range of associated GHG emissions depending on the system that is selected. The judgment calls made and the assumptions utilized will drive vastly different results. Thus, the results obtained are unlikely to be credible.

69. If life cycle emissions impact is to be considered as part of the compliance with the CLCPA GHG emissions targets, there needs to be consistency across all technologies being evaluated. However, consistency will be difficult to achieve considering the wide ranges of GHG assumptions that are used to make these estimations. Due to the complexity of the analysis and the difficulty of accurately determining the LCA for implementation of a particular facility, LCA should not be a major consideration in the characterization of utility-scale emissions sources.

QUESTION 8 – RENEWABLE NATURAL GAS

Given that the feedstocks and other resources required to produce renewable natural gas are limited and will be in demand in other sectors of New York’s economy, how should this fuel be considered in the context of this proceeding?

70. RNG is a high-Btu gas made from the decomposition of organic material that is fully interchangeable with natural gas and can be injected into a natural gas pipeline. The technology is mature, with 230 RNG projects operating in 2022. For example, landfill

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gas (“LFG”) has been recovered and processed into high-Btu RNG and directly injected into the National Grid pipeline (474,119 MMBtu/yr.) for more than 30 years at the Fresh Kills Landfill in Richmond, New York, prior to the landfill’s closure in 2002.\textsuperscript{84}

71. Municipal solid waste (“MSW”) landfills are the third-largest human-generated source of methane emission in the United States, releasing approximately 103.7 million tons of CO\textsubscript{2} in 2021.\textsuperscript{85} Methane is a GHG with a global warming potential more than 25 times CO\textsubscript{2}. Reducing methane emissions from MSW landfills will contribute to mitigating global climate change. United States landfill annual waste in 2018 was 292.4 million tons with more than 146 million tons (50\%) sent to landfills.\textsuperscript{86} LFG to energy projects as of July 2023 in the United States total actual generation was 1,287 MW with a total rated capacity of 1830 MW and LFG flow of 973.2 mmscfd resulting in an avoided emission reduction of 8.72 MMTCO\textsubscript{2}e/yr.\textsuperscript{87} LFG to energy projects as of July 2023 in the State of New York total actual generation was 84.2 MW with a total rated capacity of 106 MW with a LFG flow of 53.8 mmscfd resulting in an avoided emission reduction of 0.465 MMTCO\textsubscript{2}e/yr.\textsuperscript{88}

72. LFG is either vented to the atmosphere or extracted to collect the gas to be flared or used in an LFG energy project. The average amount of LFG flared is about 30\% of the amount

\textsuperscript{84} Id.


\textsuperscript{88} Id.
collected. Advanced treatment of the LFG removes impurities and compresses the gas to a high-Btu gas (RNG) that can be injected into a natural gas pipeline. About 16% of currently operating LFG energy projects create RNG.

73. RNG feedstock can be considered as a “drop-in” fuel for gas turbines to provide dispatchable generation. As of end of 2021, there were 230 RNG projects operating in the United States.

74. With 50% of the Achievable Deployment from Anaerobic Digestion and Thermal Conversion used to fuel gas turbines, an estimated 5.80% of the dispatchable generation needed for 27 GW and 3.5% for 45 GW could be provided. RNG can be used as a dispatchable source to maintain grid reliability and complement renewable and battery storage facilities that cannot meet electric demand. As the NY Renews Policy Committee has stated, “[o]ther beneficial uses for RNG might also include . . . backup generation support for grid reliability as we transition to 100 percent renewable energy.” For these reasons, RNG should be considered as one of the many “all of the above” strategies to provide zero emitting dispatchable generation.

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RNG Feedstock Estimate Achievable: 89.8 tBTU/yr x BTU Diff RNG to NG (0.95) x 50%
deployment = 44.2 tBTU/yr
Dispatchable Capacity Factor for Gas Turbine Plant: 31%
Gas Turbine Efficiency: 34% equivalent to 10,035 Btu/kWh
Generation = 4250 GWh \( \left( \frac{44.2 \text{ tBtu/yr}}{10,035 \text{ Btu/kWh}} \right) \times 1,000,000 \)
Capacity = 1.58 GW \( \left( \frac{4250 \text{ GWh}}{8760 \times 0.31} \right) \)

**QUESTION 9 – CLEAN ENERGY STANDARD TIERS**

*In what ways might a program to meet the Zero-Emission by 2040 Target require
reexamination and possibly revision of different tiers of the Clean Energy Standard?*

*Should one or more of the policy approaches that have been used to implement the CES be
considered to meet the Zero-Emission by 2040 Target?*

75. The CES program operates to provide renewable resources and nuclear facilities renewable
energy credits and zero emission credits, respectively, for generating energy on an
emissions-free basis, which are funded by load-serving entities so that New York may meet
clean energy and climate goals. Since its adoption, the compliance processes have changed
as the programs have matured, deadlines have been accelerated, and more obligations have been added. As stated in the Climate Action Council Scoping Plan, “the 100x40
requirement presents significant challenges that cannot currently be met by the deployment .
. . of existing technologies” such as energy efficiency, renewables, and energy storage
technologies.\(^94\) As stated previously, NYISO studies have identified a need for 27 GW to
45 GW of zero-emissions, dispatchable electricity generation by 2040 to meet projected
demand and reliability requirements. The generation and storage technologies
recommended in this affidavit, such as RNG, CCS, nuclear, and hydrogen, have the
potential to close the gap between the capabilities of existing renewable energy technology and

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\(^{94}\) Scoping Plan at 252.
expected future system reliability requirements. To ensure adequate innovations are realized and these technologies are developed to be fully capable of providing the needed operating flexibility by 2040, the Commission should adopt programs to provide the required investment and incentivization. To do so, the Commission could elect to establish a new tier under the CES program as it has done in the past where a nascent industry required incentives directed to its continued development for implementation in New York.

**QUESTION 10 – JUST TRANSITION**

What is necessary to align a program to meet the Zero-Emission by 2040 Target with the priority of just transition embedded within the CLCPA?

76. Renewable energy systems typically require fewer operating personnel than thermal power plants, so employment impacts will have to be considered. Power generation facilities, utilizing net zero GHG emissions technologies such as new nuclear, hydrogen, CCS and RNG, will require similar numbers of operating staff with similar training as existing thermal and nuclear power stations.

77. Existing or future generating sites in Disadvantaged Communities could host ambient air and/or water quality measurement stations to track the progress in achieving the State’s climate change initiatives.

78. This concludes my affidavit.

Sworn to before me this 16th day of August, 2023

David W. Cohn

Notary Public

OFFICIAL SEAL

BRENDA CAMPBELL

NOTARY PUBLIC - STATE OF ILLINOIS
MY COMMISSION EXPIRES:08/27/23
Exhibit A – Resume of David W. Cohn
DAVID W. COHN
Vice President
Sargent & Lundy Consulting Group

Education
- MS Mechanical Engineering—University of Illinois at Urbana-Champaign—Illinois, USA—1991
- BA Physics—Northwestern University (Phi Beta Kappa)—Illinois, USA—1989

Registrations
Professional Engineer (Illinois)

Proficiencies
- Feasibility Studies
- Capital Improvement Planning
- Owner’s Engineering
- Operations & Maintenance
- Independent Engineer Reviews
- Plant Design Engineering
- Thermal Power Plants
- Renewable Energy
- Project Finance
- Utility Economics

Responsibilities
David Cohn directs Owner’s Engineering efforts for thermal, solar wind, desalination, hydrogen, and ammonia projects from the feasibility stage through construction completion.

He also has direct operating experience in large central station power plants. His operating experience includes solid-fuel fired, combined-cycle, hydroelectric, and diesel engine power plants. He is also familiar with both technical and economic aspects of electric transmission systems, as well as natural gas and liquid hydrocarbon pipeline systems.

David also directs economic and financial evaluations of utility and independent power supply systems, including new generating technologies, plant upgrades, clean air technologies, bid evaluations, and financing alternatives. He performs independent engineer reviews of project performance, budgets, and contracts, including assessment of project construction, operation, fuel supply, and market risks. He is knowledgeable with the key elements of project finance and development.
Sargent & Lundy Experience

Owner’s Engineer

*Corporación Dominicana de Empresas Eléctricas Estatales | 2021–Present*
Project Director for technical audit of design, construction, commissioning, and testing of a 2x375 MW coal-fired power plant in the Dominican Republic.

*Adab Menang Sdn Bhd | 2021–Present*
Project Director for owner’s engineer effort including design review and construction oversight services for a 1,200 MW gas-fired combined-cycle power plant in Malaysia.

*ACWA Power Sidarya | 2021–Present*
Project Director for owner’s engineer effort including design review and construction oversight services for a 1,500 MW gas-fired combined-cycle power plant in Uzbekistan.

*Centrais Eletricas de Barcarena, S.A. | 2020–Present*
Project Director for owner’s engineer effort including design review and construction oversight services for a 600 MW gas-fired combined-cycle power plant in Brazil.

*Kelar S.A. | 2014–2016*
Project Director for complete owner’s engineer effort including design review and construction oversight services for gas-fired combined-cycle power plant in Chile.

*Korea Electric Power Company (KEPCO) | 2014–2016*
Project Director for bidding activities associated with three Mexican combined-cycle IPP proposals including technology evaluation, specification development, and EPC proposal conformation.

**Confidential Clients**

- 2011 | Project Manager for owner’s engineer effort for coal-fired power plant in the Dominican Republic.
- 2011 | Project Manager for owner’s engineer effort for coal-fired power plant in Chile.

*IC Power S.A. | 2009*
Project Manager for owner’s engineer effort for conversion of simple cycle power plant to combined cycle.
Feasibility Studies

Confidential Client | 2021–2022
Project Director for technical and economic feasibility study for a barge-mounted 400-MW open cycle power plant in Africa.

Engro Powergen | 2016
Project Director for technical and economic feasibility study for a 450-MW combined-cycle power plant in Pakistan.

Confidential Clients
- 2014 | Project Manager for technical and economic feasibility study for a 100–200-MW solid-fuel fired power plant.
- 2007 | Project Manager for technical and economic feasibility study for a 100–200-MW solid-fuel fired power plant.
- 2007 | Project Manager for technical and economic feasibility study for a 250-MW solid-fuel fired power plant.
- 2003 | Project Manager for technical and economic feasibility study for a 30–75-MW petcoke fired power plant.

Renewable Energy

Noor Energy | 2018-Present
Project director for lender’s engineer activities for a 700-MW concentrating solar tower + 250 MW PV hybrid solar project in Dubai. Services include independent engineer review of the design, construction, and performance testing of the project.

Aurora Solar Project Lender Group | 2018
Project director for lender’s engineer activities for a 150-MW concentrating solar tower project with molten salt storage in Australia. Services include independent due diligence assessment and construction monitoring.

Inter-American Development Bank and Other Lenders | 2015–2017
Project director for lender’s engineer activities for a 110-MW concentrating solar tower project with molten salt storage. The project is located in northern Chile. Services include independent due diligence assessment and construction monitoring.
Project director for Lenders’ engineer activities for Inka Wind Project in Peru.

Thomas Lloyd Group/International Finance Corporation | 2014
Project director for Lenders’ engineer activities for biomass and solar PV projects in the Philippines.

Enel Greenpower North America | 2013
Project director for completion certificate preparation for Section 1609 grant for Cove Fort geothermal project in Utah.

International Finance Corporation | 2009–2011
Project manager for Lenders’ engineer activities for Canakkale (30 MW) and Dagpazari (39 MW) wind projects in Turkey.

Southern California Edison | 2005

Operations Monitoring & Optimization

Confidential Clients
- 2022 | Project Director for outage planning and execution support for a 135-MW coal-fired power plant in Indonesia
- 2019–Present | Project Director for technical support for fuel switching for two 700-MW coal-fired units in Indonesia
- 2017 | Project Director for operations and maintenance review of two coal-fired power plants in Malaysia.
- 2009 | Project manager for performance and operations optimization assessment including recommendations for outage cycle improvement, heat rate improvement, and maintenance efficiency improvement at a two-unit combined-cycle facility in Chile.

GN Power Mariveles | 2017
Project Director for operations and maintenance review of a two-unit coal-fired power plant in the Philippines.
AES GENER S.A. | 2010–2011
- 2011 | Project manager for development of critical capital improvement item list for two coal-fired units in Chile.
- 2010–2011 | Project manager for root cause analysis review of tube failures and scheduled outage scope review for two coal-fired units.
- 2007 | Performed mechanical and operations optimization assessment including recommendations for outage cycle improvement, heat rate improvement, and combustion efficiency improvement at a two-unit coal-fired facility in Chile.

Mid American Energy | 2008
Provided input and technical details for 10% capacity increase for Council Bluffs (Walter E. Scott) Energy Center Unit 3. Evaluations included fan capacity, boiler feed pump capacity, condensate pump capacity, and boiler sectional evaluations.

Mirant Mid-Atlantic | 2006
Performed mechanical and operations optimization assessment including recommendations for outage cycle improvement, heat rate improvement, and combustion efficiency improvement at two coal-fired facilities.

Inter-American Development Bank | 2000–2007
Operations monitoring including availability analysis, thermal efficiency analysis, and financial review of a 96-MW diesel engine facility in Panama.

Bank of Tokyo-Mitsubishi | 2004
Operations monitoring including availability analysis, thermal efficiency analysis, and financial review of 1,000-MW gas-fired combined cycle facility in Mexico.

International Finance Corporation
- 2002 | Operations monitoring including availability analysis, thermal efficiency analysis, and financial reviews at a 50-MW facility in Senegal.
- 2001–2003 | Operations reviews including availability analysis, thermal efficiency analysis, procedure review, failure analysis, staffing analysis, and chemical control analysis at a 170-MW combined cycle and boiler facility in the Dominican Republic.

Power Plant Siting & Permitting

Confidential Client | 2008
Project Manager for preliminary siting activities related to the construction of a 500-MW combined cycle gas turbine power plant and associated desalination facility in Peru.
Constellation Power Development

- 2000 | Performed permitting activities related to the construction of a 300-MW simple-cycle gas turbine power plant in Illinois.

Specifications

Engro Powergen | 2016
Project Manager for preparation of a complete EPC specification for a 450-MW combined-cycle power plant in Pakistan.

Confidential Clients

- 2015 | Project Manager for preparation of a complete EPC specification as well as bid evaluation for a 2x300-MW coal-fired power plant in Pakistan.
- 2008 | Project Manager for preparation of a complete EPC specification for a 500-MW combined-cycle power plant and desalination facility in Peru.
- 2004 | Project Manager for preparation of a complete EPC specification for a 50-MW petcoke fired CFB power plant.

Asset Transactions

Starwood Energy | 2017
Project director for asset acquisition technical due diligence of a 1.2-gigawatt portfolio consisting of four coal-fired power projects. Two of the projects are in New Jersey, one is located in West Virginia and the other is in Arkansas.

Intergen | 2017
Project director for sell-side technical due diligence of combined-cycle assets including 2,200 megawatts comprising six combined-cycle gas turbine projects and a 155-MW wind project.

Powertek Berhad | 2006
Due diligence of two 480-MW gas-fired boiler facilities in Egypt and three simple and combined cycle facilities in Malaysia.

Salt River Project | 2002
Project Manager for technical and financial due diligence review of a 500-MW gas-fired combined cycle facility.
Confidential Clients

- 2001 | Project Manager for asset acquisition due diligence of generating facilities and projects under development in the United States and the Dominican Republic. Facilities included pulverized coal, circulating fluidized bed, stoker, and combined-cycle facilities.
- 1999 | Performed technical due diligence review of gas-fired assets of a major utility in the southern United States.

Total Fina Elf | 2001
Performed technical and financial due diligence review of assets in Argentina consisting of six steam-powered units of Central Puerto with a capacity of 979 MW; a 2x2x1 combined-cycle facility with a capacity of 769 MW, also at Central Puerto; a 2x2x1 combined-cycle facility at Salta, with a capacity of 633 MW; a 1,400 MW hydroelectric plant; and a 345-kV international interconnection transmission line. Provided an assessment of the mechanical condition of the assets, expansion plans, performance levels, and O&M practices, O&M costs, and projected capital expenditures.

Wisvest Corp. | 1999
Evaluated generation market in the northeastern United States and provided valuations of various generation assets in that region for client desiring to acquire generating capability in that area.

Reliant Energy | 1998
Performed technical and financial due diligence of generation assets

Lender’s Independent Engineer Reviews

Gas Natural Açu II | 2020–Present
Project Director for independent engineer review of the design, construction, and performance testing of a 1,600 MW combined-cycle power project in Brazil using LNG.

Electricidad del Pacifico | 2018–Present
Project Director for independent engineer review of the design, construction, and performance testing of a 290-MW reciprocating engine power project in El Salvador using LNG.

Gas Natural Açu I | 2018–Present
Project Director for independent engineer review of the design, construction, and performance testing of a 1,300 MW combined-cycle power project in Brazil using LNG.

ACWA Power | 2016–Present
Hassyan Clean Coal Project. Project Director for independent engineer review of the design, construction, and performance testing of a 4x600 MW coal fired power project in Dubai.
BNP Paribas | 2009–2015
Project Manager for technical due diligence review of a project consisting of five substations and five transmission lines in Peru.

International Finance Corporation, Akbank, and European Investment Bank | 2007–Present
Project Manager and Project Director for technical and environmental due diligence review ten hydroelectric projects, a thermal power plant project, and a wind power project in Turkey.

Inter-American Development Bank
- 2006–Present | Project Manager for technical and financial due diligence review of transmission system project including installation of 150 km of transmission lines in Chile.
- 2006 | Project Manager for technical due diligence review of a new coke production facility in Brazil.
- 2004–Present | Project Manager for technical and financial due diligence review of transmission system project including installation of 600 km of transmission lines and five major substations in Bolivia.
- 2004 | Technical review of a 230-MW pet coke-fired CFB power plant in Mexico. Identified design limitations and discrepancies in proposed modifications to design.
- 2002 | Project Manager for technical and financial due diligence review of corporation and assets of Transredes, S.A., the Bolivian gas and hydrocarbon liquids pipeline company.
- 2000 | Project Manager for technical and financial due diligence review of newly installed transmission system equipment including 1,045 km of transmission lines and four major substations in Peru.
- 1999 | Performed technical and financial due diligence of a greenfield combined-cycle power plant project in Mexico for major international trade finance banking institution.

BBVA | 2004
Technical and financial due diligence of an upgrade of a simple-cycle plant near Lima, Peru to combined-cycle.

Confidential Client | 2003
Review of long-term layup procedures for three GE 7241FA combustion turbines.

Nord LB | 2003
Project Manager for operations monitoring due diligence review of a 100 million cubic foot per day natural gas compression station.

Deutsche Banc Alex. Brown and Bank of Tokyo-Mitsubishi | 2002
Project Manager for technical and financial due diligence of a 1,000-MW greenfield gas-fired combined-cycle power plant project in Mexico for major investment banks.
International Finance Corporation

- 2001 | Performed operational assessment due diligence review of an existing generation facility in the Dominican Republic finding significant risks in the areas of boiler chemistry, work processes, and staffing.
- 1999 | Performed contract review and financial due diligence for an 1,100-MW greenfield hydro facility in Brazil.

Exelon Corporation | 2001
Technical Lead in the due diligence review of existing fossil generation facilities in the Exelon portfolio in support of bond rating activities.

Illinois Power Company | 1999
Performed technical due diligence review and prepared financial pro forma for a $900 million financing associated with generating assets in the Midwestern United States which was marketed to over 50 banks and was fully subscribed.

Credit Suisse First Boston | 1999
Performed technical and financial due diligence of a greenfield coal-fired power plant project in China.

Capital Planning

New Madrid Unit 1 Capital Expenditure Plan | 2016
Reviewed condition assessment data associated with maintenance of New Madrid Unit 1 including for appropriateness and long-term effect on EFOR.

AEP Tanner’s Creek Capital Expenditure Plan | 2003
Reviewed projects associated with major maintenance of Tanners Creek Unit 4 including cyclone replacement, LP turbine disk replacement, and economizer replacement for appropriateness and long-term effect on EFOR.

ComEd
Joliet Station No. 29
- 1994 | Coal Pulverizer Upgrade Program | Directed equipment evaluation, selected upgrade components, and provided business case justification for major pulverizer upgrade at 1,100 MW coal-fired power plant.
- 1995 | Feedwater Heater Controls Replacement | Co-designed modification and provided business case justification.
1995 | EFOR Outage Plan | Identified major root causes of lost availability and developed prioritized list of capital improvements.

1995 | CEM Installation | Managed project installation process.

**Business Strategies & Special Studies**

*TXU, Inc. | 2004*
Prepared discounted cash flow (DCF) valuation model for several generating assets using market data and estimates of operations and maintenance costs.

*Electricidad de Caracas | 1998*
Evaluation of technology options for electric generation in El Salvador market.

*General Electric Company | 1997*
Evaluation and selection of partners for joint-venture operations in Latin America.

**Languages**

- English, Spanish, & Italian (Fluent)
- French & Portuguese (Working Proficiency [Read/Write/Speak])
- German (Working Proficiency [Read/Write])

**Publications**


Exhibit B – Sargent & Lundy Experience
Renewable Energy and Energy Storage

Qualifications and Experience

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About Sargent & Lundy

Sargent & Lundy is one of the longest-standing full-service architect engineering firms in the world. Founded in 1891, the firm is a global leader in power and energy with expertise in grid modernization, renewable energy, energy storage, nuclear power, fossil fuels, carbon capture, and hydrogen. Sargent & Lundy delivers comprehensive project services – from consulting, design, and implementation to construction management, commissioning, and operations/maintenance – with an emphasis on quality and safety. The firm serves public and private sector clients in the power and energy, gas distribution, industrial, and government sectors.

Our expert staff, state-of-the-art facilities, and project resources enable Sargent & Lundy to conduct meaningful work around the globe. We serve worldwide power markets through our headquarters in Chicago, Illinois, our numerous US satellite offices, and our international and joint venture offices in India, Saudi Arabia, South Korea, and the UAE. In addition, we have strategic partners in South America and Africa to support our project activities in their regions.

For more information, please contact:
Matthew R. Thibodeau | Senior Vice President
+1-312-269-7633 | mthibodeau@sargentlundy.com
Wind Power

Sargent & Lundy has provided services to the wind power industry since the turn of the century. We provide a range of services for wind project developers, contractors, owners, lenders, and investors:

- Full Plant Design
- Site Screenings
- Project Feasibility Studies
- Wind Resource Assessments
- Independent Engineering
- Interconnection Planning
- Conceptual Engineering
- Contract Development
- Detailed Engineering
- Design Reviews
- Construction Monitoring
- Commissioning
- O&M Support

We have experience with a variety of wind turbine generators, including models from Acciona, Clipper, Enercon GmbH, GE, Goldwind, Kenersys, Mitsubishi, Nordex, Senvion, Siemens Gamesa, Sinovel, Suzlon, and Vestas.

We participate in both the AWEA Offshore Wind Working Group and the AWEA Wind Power O&M Working Group. We also actively participate in the IEEE Wind Plant Collector Design Working Group.

The following recent projects provide an overview of Sargent & Lundy’s wind energy experience.

Sargent & Lundy participated in and was actively involved in the American Society of Civil Engineers (ASCE)/American Wind Energy Association (AWEA) committee that prepared a US code for the design of wind turbine foundations.
Due Diligence and Independent Engineering

Selected Recent Project Experience

ARES Energy Investors

2018 | Texas | Performed a full independent engineering due diligence for a partial repower of three wind facilities:

- 60 MW | Silver Star
- 145 MW | Sherbino Mesa II
- 225 MW | Trinity Hills

Apex Clean Energy Management

2018 | 249 MW | Chapman Ranch Wind Project | Performed an independent engineering review of P&H wind turbine foundation design.

Blattner Energy

- 2021–2023 | United States | Provided an independent design review of all requirements and computations to confirm the engineer of record’s foundation design results at three sites. The sites were as follows:
  - 43.2 MW | Texas | Blue Summit I
  - 98.9 MW | Oregon | Vansycle II
  - Kansas | High Banks Wind Energy Center
- 2022 | 173.6 MW | Texas | Great Prairie Gruver Expansion | Provided an addendum to a previous letter report to include a 173.6-MW expansion. Reviewed the updated geotechnical investigation to confirm that the subsurface conditions indicate that the existing wind turbine foundation design is appropriate for the expansion. Reviewed the revised wind turbine foundation design drawings and calculation to confirm that updates only indicate that the design applies to the expansion.
- 2022 | Minnesota | Buffalo Ridge Wind Project | Provided an independent design review of all requirements and computations to confirm the engineer of record’s foundation design results. Evaluated the design methodology to determine whether the engineer of record correctly applied applicable code requirements and whether they follow industry standards and practices. The assessment included a detailed review of design inputs and outputs to determine whether the results were reasonably accurate or conservative.
- 2022 | Minnesota | Walleye Wind Project | Performed an independent design review of all requirements and computations to verify the engineer of record’s foundation design results. Reviewed the design methodology to determine whether the engineer of record correctly applied the applicable code requirements and whether they were in accordance with industry standards and
practices. The assessment also included a detailed review of design inputs and outputs to determine whether the results were reasonably accurate or conservative. Under a separate scope, also performed an independent design review of all requirements and computations to verify the engineer of record’s foundation design results. Reviewed the design methodology to determine whether the engineer of record correctly applied the applicable code requirements and whether they were in accordance with industry standards and practices. The assessment also included a detailed review of design inputs and outputs to determine whether the results were reasonably accurate or conservative.

- 2022 | Texas | Young Wind Project | Reviewed, evaluated, and opined on four foundation designs intended to support GE turbines. Performed an independent design review of all requirements and computations to confirm the engineer of record’s foundation design results.

- 2021–2022 | 126.9 MW | Iowa | Kossuth Wind Energy Center | Provided an independent design review of two wind turbines (2.52 MW and 2.8 MW). Design review considered foundation strength, stability, and fatigue resistance; incorporation of design recommendations from codes, standards, and guidelines; appropriateness of foundation materials and components; and foundation constructability. Reviewed all requirements and computations to confirm the engineer of record’s foundation design results.

- 2021–2022 | 870 MW | Texas | Great Prairie Wind | Provided an independent design review of all requirements and computations to confirm the engineer of record’s foundation design results. Evaluated the design methodology to determine that the engineer of record correctly applied the applicable code requirements and that it is in accordance with industry standards and practices. The assessment included a detailed review of design inputs and outputs to determine that the results met code requirements and were reasonably accurate or conservative.

- 2018 | Trent Mesa & Desert Sky | Performed an independent engineering review and post-processing of raw instrument data.

- 2018 | Conducted data processing and an analysis of wind turbine foundation data from operating wind turbines to support partial repowering.

**BP Wind Energy**

- 2021 | 470 MW & 248 MW | Kansas & Colorado | Flat Ridge II & Cedar Creek II Wind Farms | Performed an asset valuation to determine the eligibility of the project’s repower plan for production tax credits based on the IRS’s “80/20 rule.” Scope included a financial analysis of the cost and depreciation of reused equipment as well as the cost and value of new equipment.

- 2019–2021 | 248 MW | Colorado | Cedar Creek II Wind Farm | Executed wind turbine foundation and tower structural analyses. Evaluated the feasibility of reusing the existing reinforced-concrete foundation and steel tower when repowering the project. Assessed the qualification of the foundation and tower designs using the stresses and loads calculated within an FEM model created using the SAP 2000 software.

- 2017–2018 | 430 MW | Sherbino Mesa II, Trinity Hills, & Silver Star | Conducted an independent engineering review of the wind projects in support of asset sale and potential repowering. Scope
included site inspections and desktop reviews of the foundations, electrical systems, and tower sections. The projects consist of 172 turbines.

Clearway Energy Group, LLC

- 2021–2022 | 345 MW | Texas | Mesquite Sky Wind Project | Performed a root cause analysis on a wind turbine tower failure. The failure occurred at a 345-MW wind facility consisting of Siemens 5.0-145 WTGs. Subcontracted the root cause analysis and worked with the subcontractor to finalize and present the findings.

Confidential Clients

- 2022 | Performed an independent engineering review to assess the project’s future performance and operational risks. The review was done to support the client and tax equity investors.

- 2022 | Performed a high-level fatal flaw review of wind turbine foundation designs to provide an opinion on whether the existing wind turbine foundations are likely to meet code requirements for each applicable design check or if a retrofit is likely to be required.

- 2021–2022 | Provided independent engineering due diligence services to support the financing of the repower and expansion to an existing wind power project. Performed a site suitability assessment with a site visit and desktop reviews. Reviewed the historical O&M costs and forecasted future costs. Provided a decommissioning review and construction monitoring reviews once the project began construction.

- 2021–2022 | Provided front-end engineering and design support for the repowering of an existing wind project. Work included foundation and tower structural assessments, electrical studies, field testing, a curtailment and congestion study, turbine site suitability and noise studies, aviation and communications impacts, permitting and site characterization assessments, 30% civil design and transportation studies, and a Class II cost estimate. Also conducted an onsite condition assessment.

- 2021–2022 | 300 MW | Kansas | Performed independent engineering reviews required under the subsequent “phase effect” clauses within development build-out agreements. Review scope included O&M, wind, and transmission interference effects of a future development upon existing wind projects.

- 2021–2022 | 130 MW | Canada | Reviewed the foundation design of wind turbines for buoyant and non-buoyant conditions. Also provided an assessment of the engineer of record’s design optimization and identified areas where efficiency could be increased in terms of cost savings and structural capacity.

- 2021–2022 | 122 MW | Texas | Performed independent engineering due diligence reviews for a wind partial repower project. Reviewed the spread-footing wind turbine foundations, the electrical BOP system—including the collection system, substation, and interconnection—and the WTG towers. Also performed an independent engineering due diligence review of the project infrastructure considering potentially uprated power.
• 2021–2022 | 519 MW | Texas | Performed an independent engineering review and evaluation of 2022–2026 operating budgets for a portfolio of projects. Compared operating budgets with base-case budgets and investigated reasons for variances. Also assessed the reasonableness of the budgets.

• 2021–2022 | Reviewed a methodology to assess the transient ampacity of wind power collection systems. Scope included a review of the methodology prepared by another consultant and a commentary on whether it was reasonable, justifiable, and financeable in concept. Specifically, reviewed the methodology from a technical perspective—providing commentary in a matrix that was resolved in correspondence with the consultant that prepared the methodology—and summarized the effort in a technical memorandum.

• 2021–2022 | 2 GW | Kansas | Performed an independent engineering due diligence review of a greenfield wind project and HVDC line in support of potential acquisition. Scope included a WTG foundation design review, electrical BOP review, site suitability/wind turbine technology and wind resource assessment, and commercial agreements/permitting review.

• 2021–2022 | Performed a condition assessment of a substation.

• 2020–2022 | 101 MW | Kansas | Performed independent engineering due diligence and monitored construction. The subsequent due diligence report included reviews of the foundation, balance of plant, tower, site suitability and technology, commercial agreement, O&M costs, and an IE certificate and reliance review. The construction monitoring report documented observations and data analyses from a site visit.

• 2021 | 57 MW | California | Performed independent engineering due diligence reviews in support of tax-equity financing for the full repower of two co-located wind projects. The goal was to assess future performance and operating risk. Work included reviews of turbine technology, site suitability, design, key contracts, environmental and permitting considerations, the financial model, and the wind energy resource assessment.

• 2021 | Performed independent engineering reviews of a fully repowered project. Prepared milestone construction reports on a monthly basis throughout construction until project completion. Assessed overall progress in construction, potential issues that might affect compliance with major schedule dates, and other technical issues that might have occurred during construction.

• 2021 | Supported a renewable energy developer for comprehending the impact of two key commodity costs on wind turbine pricing. Focused on structural steel and fiberglass epoxy resin commodity cost impacts. Scope included identification of the appropriate steel and epoxy resin commodities, quantification of the mass of each commodity within each turbine, and an assessment of price changes over time for each commodity.

• 2020 | Colorado, Iowa, North Dakota, Oklahoma, Texas, & South Dakota | Performed independent engineering due diligence of five partial repower wind projects to support tax-equity investors. Scope included a detailed review and analysis of the existing foundations as well as a review of the existing electrical BOP and turbine towers.
• 2019–2021 | 100 MW | Oregon | Performed independent engineering services for a wind project. Scope included observing the EPC contractor’s execution of project construction, startup, and commissioning as well as confirming work compliance with the EPC agreement. Reviewed project design documents, conducted site visits to observe the EPC contractor’s work execution, verified project construction milestones, and reviewed the project punch list.

• 2019–2020 | 680 MW, 210 MW, 250 MW, & 220 MW | Brazil | Performed acquisition support due diligence of operating and development-stage wind projects. Support included reviews of turbine technology, historical and forecasted performance, the O&M program, commercial agreements, and permits.

• 2019–2020 | 75 MW | Florida | Performed independent engineering services and observed the EPC contractor’s execution of project construction, startup, and commissioning while confirming work compliance with the EPC agreement. Also reviewed project design documents, conducted weekly site visits to observe the EPC contractor’s execution, verified project construction milestones, and reviewed the project punch list.

• 2019 | 200 MW | Wyoming | Observed the EPC contractor’s execution of project construction, startup, and commissioning while confirming work compliance with the EPC agreement. Reviewed project design documents, conducted site visits to observe the EPC contractor’s execution, verified construction milestones, and reviewed the project punch list.

• 2019 | 142 MW & 223 MW | Brazil | Performed independent engineering due diligence of operating and development-stage wind projects. Scope included reviews of project design, turbine technology, historical and forecasted performance, the O&M program, commercial agreements, and permits.

• 2018 | New Mexico | Conducted an independent review of a wind resource assessment and O&M contracting.

• 2018 | Colorado | Conducted an independent engineering review and assessment of the wind project’s interconnection request feasibility study.

• 2018 | Illinois | Performed an independent engineering review and assessment of costs associated with a wind project’s substation upgrades.

• 2018 | Evaluated 12 greenfield wind projects to support tax equity investment. Scope included an assessment of the wind turbine foundations, electric BOP design, and construction.

• 2018 | Evaluated five repower projects to support tax equity investment. Scope included a full analysis of wind turbine foundations, foundation inspections, tower inspections, electric BOP design, and construction.

• 2018 | Evaluated a fully repowered wind project to support tax equity investment. Scope included an assessment of the wind turbine foundations, electrical BOP, commercial agreements, and O&M cost projections.
ContourGlobal

2014–2019; 2021 | 114 MW | Peru | Inka Wind Project | Performed an independent engineering review of the 2022 annual operating budget for a portfolio of wind projects in South America. Projects began commercial operation in 2014 and were financed by bond holders through a trust indenture. Supported project owners by certifying their 2022 annual operating budget for compliance with the trust indenture agreement. Under previous scopes of work, reviewed O&M budgets and performed an independent engineering review to support bond offering. Also performed a technical review of the project, which included the financial statement, wind resource assessment, wind turbine technology and suitability, wind turbine foundations, power collection system, SCADA system, interconnection, and key contracts.

E.ON Climate & Renewables

2018 | 201 MW | Texas | Stella Wind Farm | Performed a detailed decommissioning cost estimate on behalf of the project owner and property owner.

Ecofin Advisors, LLC

2021 | 60 MW | Texas | Whirlwind Wind Power Project | Provided independent engineering reviews in support of the prospective acquisition of a wind power plant that consists of 26 WTGs. Reviewed recent performance as well as the O&M costs of the plant to determine their reasonableness.

Fagen, Inc.

- 2022 | 240 MW | Texas | Blackjack Wind Project | Reviewed, evaluated, and commented on a wind turbine foundation design and constructability. Performed a site visit to review a mock remediation and provided onsite construction oversight of the wind turbine foundations.
- 2009–2019 | Conducted reviews and evaluations of wind project electrical and foundation designs for over 20 projects.
- 2018 | Iowa | Saratoga Wind Farm | Performed an independent engineering third-party foundation design review.
- 2018 | Palmers Creek Wind Farm | Performed an independent engineering review. Also reviewed the RUTE foundation design.

GlidePath Advanced Energy

- 2018 | Performed due diligence reviews of seven operating wind projects in support of asset acquisition.
- 2018 | Performed due diligence reviews in support of the acquisition of 10 wind projects.

IC Power

2018 | Dominican Republic | Agua Clara Wind Farm | Reviewed the project foundation design.
JBS Energy Solutions LLC

- 2022 | California | Strauss Wind Project | To address safety challenges, performed a two-day site visit to evaluate the implementation of safety measures. Also provided recommendations to mitigate the reoccurrence of safety incidents based on the site’s topography and civil design. Subsequently provided a letter report summarizing the findings. As a separate scope of work, evaluated and commented on a preliminary wind turbine foundation design. Provided an independent design review of all requirements and computations to confirm design results. Also reviewed the design methodology to confirm the correct application of code requirements and adherence to industry standards and practices.

- 2018 | Kimball Wind Farm | Performed an independent engineering review of P&H tensionless pier shear reinforcement.

Leeward Renewable Energy, LLC

- 2021–2022 | 145 MW | Colorado | Panorama Wind Project | Supported financing via reviews of the wind turbine foundations, the electrical balance of plant, turbine technology, commercial agreements, and the financial model. Also performed monthly monitoring throughout construction.

- 2021 | 61 MW | Illinois | Crescent Ridge Wind Project | Performed independent engineering due diligence in support of financing. Services included reviews of wind turbine foundations, the electrical balance of plant, the wind resource assessment, commercial agreements, and the financial model. Also performed monthly construction monitoring until project commissioning.

- 2020 | 56 MW | Illinois | Crescent Ridge Wind Project | Performed an independent engineering analysis of a wind turbine generator removal procedure for the decommissioning of a wind project. Considered the traditional tilt-fell method as well as the modified tilt-fell (energetic felling by blasting) method.

- 2019 | 76 MW | Illinois | Mendota Hills Wind Farm | Provided an independent engineering opinion on a third-party arc flash risk assessment. Also opined on the aspects of a switchgear cabinet installation.

- 2018–2019 | 76 MW | Illinois | Mendota Hills Wind Farm | Conducted an independent engineering due diligence review for a full project repower. Also conducted decommissioning analyses and provided construction monitoring services.

- 2018 | 37.5 MW | Texas | Sweetwater 1 Wind Farm | Performed a wind turbine foundation review for a possible update. Also conducted independent due diligence services for a partial repower. Scope included a foundation review, electrical BOP review, condition assessment, wind energy assessment, and O&M cost assessment.

Mitsui & Co., Ltd.

2018 | 60 MW | Argentina | Vientos los Hercules Wind Project | Conducted independent engineering reviews and a turbine foundation evaluation.
Na Pua Makani Power Partners, LLC

2020 | 28 MW | Hawaii | Na Pua Makani Wind Project | Provided an independent engineering review on the wind turbine foundation design to confirm the engineer of record’s results in support of financing. Also reviewed QA/QC documentation from construction and opined on a repair method used on two damaged anchor bolts. Additionally performed an electrical loss study to compute losses between the WTG low-voltage terminal and the POI.

NextEra Energy Resources, LLC

- 2022–2023 | United States | Performed independent engineering reviews for a portfolio of operating wind facilities. Provided an assessment of the project’s equipment and configuration, operating history, and projected performance. The reviews were performed in support of financing of the project. The sites were as follows:
  - 250 MW | Texas | Javelina I
  - 249 MW | Colorado | Golden West
  - 200 MW | Missouri | Osborn
  - 160 MW | Nebraska | Sholes
  - 150 MW | California | Alta VIII
  - 150 MW | North Dakota | Brady I
  - 149 MW | North Dakota | Brady II
  - 101 MW | Oklahoma | Elk City II
  - 99 MW | North Dakota | Oliver III
  - 80 MW | Iowa | Sac County

- 2022 | 350 MW | Texas | Inertia Wind Project | Reviewed a project-specific transient ampacity methodology and supporting documentation and provided a markup with feedback for client consideration.

- 2022 | 839.24 MW | Indiana, Iowa, Oregon, & North Dakota | Rose Wind Portfolio | Completed a bringdown independent engineering report on a portfolio of four wind projects in the US to support refinancing of the portfolio. The assessment was performed to determine if conclusions had changed since performing due diligence when the portfolio was constructed three years prior. The scope of the assessment included a balance-of-plant design review (overall design and configuration, wind turbine foundation, collection system, and interconnection design), construction review, and review of contracts and agreements.

- 2022 | United States | Performed an independent engineering review and evaluation of project infrastructure in consideration of the repowered WTGs and the client’s desired 20 additional years of operating life. Divided the project into three tasks: Task I: Reviewed the spread-footing wind turbine foundations; Task II: Reviewed the electrical balance-of-plant system, including the
collection system, substations, and interconnection; and Task III: Reviewed the WTG towers. The sites were as follows:

- 135.4 MW | Texas | Blue Summit I Wind Project
- 98.9 MW | Oregon | Vansycle II Wind Project

- 2022 | 446 MW | Iowa and New Mexico | McKay Wind Portfolio | Completed a bringdown independent engineering report on a portfolio of four repowered wind projects in the United States to support refinancing of the portfolio. Performed an assessment to determine if anything had changed since due diligence was performed three years prior. The scope of assessment included the wind turbine foundation review, balance-of-plant electrical system review, and wind turbine tower review.

- 2022 | 99 MW | New Hampshire | Granite Reliable Wind Energy Center | Prepared a decommissioning plan and cost estimate. The decommissioning plan covered the anticipated life of the facility, the manner in which the facility will be decommissioned, and a description of any expected effects on present and future natural resource development. Also considered state, local, and project-specific decommissioning requirements, including the New Hampshire Administrative Code, Title Site, Chapter 300, Section Site 301.08(a).

- 2021–2022 | 800 MW | Kansas, New Mexico, & Texas | Stargrass Portfolio | Performed independent engineering due diligence reviews for a portfolio of wind projects consisting of greenfield projects as well as a wind partial repower project. For the greenfield projects, new GE 3.03-MW, 2.82-MW, 2.3-MW, and 2.32-MW WTGs were installed. Reviewed the BOP design, construction progress, quality control documentation, and portfolio contracts. For the repower project, existing Siemens 2.3-MW WTGs were either partially repowered to Siemens 2.66-MW and 2.3 MW-WTGs with larger rotor diameters or fully replaced with GE 2.3-MW WTGs with larger rotor diameters. Reviewed the spread-footing wind turbine foundations, the electrical BOP system—including the collection system, substation, and interconnection—and the WTG towers.

- 2021–2022 | Texas | Pioneer Hutt Wind Project | Visited the site to confirm that: (i) the wind turbine foundation’s excavation work had been performed; and (ii) none of that foundation excavation work had been materially upgraded, redone, reworked, or removed from its original completion. Original work was performed pursuant to IRS guidelines for production tax credit (PTC) qualification under Section 45 of the Internal Revenue Code of 1986 as amended. Also opined on whether the foundation excavation work is fit for the prospective wind turbine model.

- 2021–2022 | 80 MW | Iowa | Richland II Wind Project | Performed an independent engineering review to provide the client and potential investors with an understanding of the overall level of risk associated with the project. Provided recommendations, where appropriate, to help prospective stakeholders mitigate potential issues and concerns. Scope of review included the BOP design, construction, quality control documentation, and project contracts.

- 2021–2022 | 279 MW | Texas | Hubbard Wind Energy Center | Reviewed and commented upon the relative domestic content value. The project was planned to consist of 108 WTGs. Performed an assessment to determine the percent of non-labor content derived from domestic (US) sources relative to the overall project non-labor costs.
2020–2022 | United Stated | Central Midway Portfolio | Provided independent engineering due diligence services in support of project financing for a renewable energy portfolio. Assessed the site and construction activities for each project in the portfolio through desktop reviews and site visits. Reviewed the design, selection of major equipment, environmental and permitting efforts, financial performance, and key contracts for each project. The sites were as follows:

- 200 MW | Colorado | Niyol Wind Project
- 62.3 MW | California | Sky River Wind Project
- 200 MW | Iowa | Heartland Divide II Wind Project

2021 | 59.8 MW | Oklahoma | Blackwell Wind Project | Conducted independent engineering due diligence reviews for an operating wind project. Performed a site visit to assess the project condition, including spread-footing foundations, electrical BOP, and SGRE 2.3-MW WTG towers. Also performed desktop reviews of project design, performance indicators, and O&M and commercial and permitting reviews.

2021 | 70.3 MW | Iowa | Crystal Lake III Wind Project | Performed independent engineering due diligence reviews for a wind partial repower project. Existing GE 1.5-MW WTGs were repowered to GE 1.6-MW and GE 1.5-MW WTGs with larger rotor diameters. Reviewed the spread-footing wind turbine foundations, the electrical BOP system—including the collection system, substation, and interconnection—and the WTG towers.

2021 | United States | Firewheel & Edmondson Wind Projects | Performed independent engineering reviews, including site visits, to confirm that foundation excavation work had been performed and that none of that foundation excavation work has been materially upgraded, redone, reworked, or removed from its original completion. Work was previously performed pursuant to the IRS guidelines for production tax credit (PTC) qualification under Section 45 of the Internal Revenue Code of 1986 as amended. Opined on whether the foundation excavation work is fit for the prospective wind turbine model.

2021 | 103.42 MW | Oklahoma | Minco II Wind Project | Performed independent engineering due diligence reviews for a wind partial repower project. Existing GE 1.6-MW WTGs were either partially repowered to GE 1.6-MW WTGs with larger rotor diameters or fully replaced with GE 2.3-MW WTGs with larger rotor diameters. Reviewed spread-footing wind turbine foundations, the electrical BOP system—including the collection system, substation, and interconnection—and WTG towers.

2018–2019 | 160 MW | Nebraska | Sholes Wind Energy Portfolio | Evaluated and verified the project to support tax equity investment. Scope included a review of BOP design and construction, interconnection facilities, and project contracts as well as construction completion verifications.

2018 | Performed independent engineering due diligence reviews of the following wind projects:

- 454 MW | Horse Hollow I (230 MW) & Horse Hollow III (224 MW) Wind Energy Centers
- 513 MW | Capricorn Ridge I, III, and IV Wind Energy Centers
- 114 MW | Callahan Divide Wind Energy Center
- 90 MW | Red Canyon Wind Energy Center
• 2018 | United States | Performed an independent engineering evaluation and completion verification reviews of several greenfield wind projects to support tax equity investment. Scope included a review of BOP design and construction, interconnection facilities, and project contracts. Also verified construction completion. The sites were as follows:
  ▪ 51 MW | Casa Mesa Wind Energy Center
  ▪ 80 MW | Texas & Oklahoma | Lorenzo Wind Energy Center, Wildcat Ranch Wind Farm, Armadillo Flats, and Pegasus Wind Farm
  ▪ 607 MW | Kansas, Iowa, & Oklahoma | Pratt Wind Energy Center, Heartland Divide Wind, Minco IV Wind Energy Center, and Minco V Wind Energy Center
  ▪ 400 MW | Texas | Torrecillas Wind (300 MW) and Blue Summit II (100 MW) Wind Energy Centers

• 2018 | 465 MW | New Mexico, North Dakota, & Oklahoma | Performed an independent engineering review of four wind projects to support repowering and tax equity investment. The scope included a full analysis of the wind turbine foundations, foundation inspections, and electric BOP design.
  ▪ 101 MW | Oklahoma | Elk City II
  ▪ 160 MW | North Dakota | Langdon Wind I (119 MW) and Langdon Wind II (41 MW) Energy Centers
  ▪ 204 MW | New Mexico | New Mexico Wind

• 2018 | 99 MW | Oklahoma | Breckinridge Wind Farm | Performed an independent engineering review of the proposed 2019 operating budget.

Patrick & Henderson

2018–2019 | Desert Sky Wind Farm, Trent Mesa Wind Farm, Snyder Wind, & Auwahi Wind | Conducted post-processing of wind turbine tower and foundation sensor data for the wind turbines.

PNE USA, Inc.

2022 | 167.28 MW | Oklahoma | Chilocco Wind Farm | Provided independent engineering services for a wind electric generating facility in two phases: Phase 1 (fatal flaw review) and Phase 2 (due diligence review). Phase 1 included balance-of-plant design review, wind resource assessment report review, PTC continuous work report review, proposals and contracts review, and environmental and permitting review. Phase 2 provided a description of the status of development for the project and assessed risk items of varying levels of severity and probability. Performed site visits to observe the site conditions and existing work.

ROUTE Foundation Systems

2018 | Reviewed several new foundation designs:
  • RUTE foundation design
• RUTE BXG 90% foundation design package
• RUTE TG foundation

Terracon Consultants, Inc.

2021–2022 | Provided independent engineering technical support in the form of reviews and comments pertaining to the basis of design of the client’s tensionless pier wind turbine foundations. Opined on other technical considerations related to this type of foundation.

Third Planet Windpower

2018 | 100 MW | Texas | Loraine Windpark | Performed independent engineering electrical and structural design reviews.

UKA North America LLC

• 2022 | Illinois | Virden Wind Project | Performed an independent engineering review of a 120-meter meteorological evaluation tower and light detection and ranging unit. Reviewed the meteorological evaluation tower geotechnical specifications, tower design drawing and calculations, and tower installation process.
• 2021 | Montana | Ponderosa Wind Project | Performed an engineering design review of the meteorological evaluation tower. The tower was planned to be used to collect wind resource data for the project.

U.S. International Development Finance Corporation (formerly Overseas Private Investment Corporation)

• 2014–2019 | 36 MW | Jamaica | Acted as lender’s technical advisor to support financing of a wind project. Performed a technical review, which included the project financial statement, wind resource assessment, wind turbine technology and suitability, turbine foundations, power collection system, SCADA system, interconnection, key contracts, construction monitoring, and operations monitoring.
• 2013–2019 | 150 MW | Pakistan | Acted as lender’s technical advisor to support financing of three 50-MW wind projects. Performed a technical review of the projects, which included the project financial statement, wind resource assessment, turbine technology and suitability, wind turbine foundations, power collection system, SCADA system, interconnection, key contracts, construction monitoring, and operations monitoring.
• 2018 | 50 MW | Master Green Wind Project | Served as lender’s technical advisor.

Utah Associated Municipal Power Systems

2021–2022 | 58 MW | Idaho | Horse Butte Wind Project | Determined the suitability of repowering existing Vestas V100 wind turbine P&H foundations for an additional design life of 20 years with proposed new WTG components. The structural analysis included finite element modeling in SAP 2000 software and fatigue analyses of critical components. Also calculated levelized cost of energy estimates.
Vestas-American Wind Technology, Inc.

2022 | United States | Performed additional field measurements of existing WTG steel towers at three project sites in the United States. Obtained measurements manually and cross-checked the measurements with 3D image scans taken during prior visits for confirmation. Measurements were used to complete a tower structure design data form. The sites were as follows:

- Pennsylvania | Allegheny Ridge
- Pennsylvania | Sandy Ridge I
- Texas | Lone Star II

Additional Project Experience

BBVA Securities

2010–2012 | Nova Scotia, Canada | Glen Dhu Wind Project | Performed an independent engineering review to support financing. The facility uses Enercon E-82 2.3-MW WTGs. Performed a technical review of project, which included the project financial statement, wind resource assessment, wind turbine technology and suitability, wind turbine foundations, power collection system, SCADA system, interconnection and grid congestion, and key project contracts.

Confidential Clients

- 2017–2018 | Conducted independent engineering evaluations to support planning for the repowering of three wind projects. Scope included a full analysis of the wind turbine foundations, foundation inspections, tower inspections, a wind resource assessment, a turbine suitability review, contract reviews, and an electric BOP design and construction review.
- 2016 | Hawaii | Provided asset acquisition due diligence services to support the client’s evaluation of a wind power project. Evaluated the wind resource, wind turbine selection, project feasibility, and economics while providing bid model inputs.
- 2011–2012 | Canada | Provided asset acquisition due diligence services to support the client’s evaluation of investing in a wind power project. Performed a technical review of the project, which included the financial statement, wind turbine technology and suitability, construction plan and schedule, interconnection and grid congestion, and key contracts.

EDF Renewable Energy

Exelon

2010 | 700 MW | Provided technical due diligence services to support the acquisition of a portfolio of 36 operating wind projects. Scope included a fatal flaw analysis, a review of operating performance, a design review, and the provision of technical and financial input into the financial model used to develop the acquisition bid.

GE Energy Financial Services

- 2017 | Performed independent engineering evaluations to support tax equity investment for 12 repowered wind projects. Scope included a full analysis of the wind turbine foundations, foundation inspections, tower inspections, and electric BOP design and construction.

- 2014–2015 | Texas, United States | Briscoe Wind Project | Acted as independent engineer to support financing.

International Finance Corporation & European Bank for Reconstruction and Development

2012–2013 | 142.5 MW | Turkey | Bares Wind Project | Supported financing by reviewing the project financial projections, contracts, wind turbine selection, designs, and construction plan and schedule. Monitored construction progress and startup on behalf of the project lenders.

Macquarie Capital

2015 | Northwestern Illinois | Big Sky Wind Project | Served as lender’s technical advisor to conduct an independent engineering review to support financing.

Patrick & Henderson

2007–2018 | Performed independent reviews and evaluations of wind turbine foundation designs for over 12 projects.

Standard Bank of South Africa


- 2011–2012 | Provided lender’s technical advisory services to support project development and bidding into the South African Renewable Energy Independent Power Producer Program.

SunEdison/TerraForm Power

- 2014 | Hawaii & Maine | Performed asset acquisition due diligence of four wind projects—three in Maine and one in Hawaii—to support the client’s acquisition of First Wind.

- 2012–2013 | Reviewed wind turbine foundation designs for three projects, considering complex geotechnical and foundation issues.
Owner's Engineer and Technical Advisor

Selected Recent Project Experience

AES

2018 | 28 MW | Hawaii | Na Pua Makani Wind Project | Conducted design engineering reviews, provided commercial agreement technical support, and offered field support. Also provided technical reviews of the key project agreements, including the EPC agreement, O&M agreement, and turbine supply agreement.

ConEd Development

2018 | South Dakota | Verified construction completion for two wind projects.

Cormint Data Systems, L.L.C.

2022 | Texas | Sherbino Mesa I Substation | Assessed the impact from expected configuration and operational changes on a substation as a result of repurposing to serve a cryptocurrency mining facility. Provided a high-voltage O&M plan and conducted a protection and coordination study.

Confidential Clients

- 2022–2023 | California | Performed a safety evaluation that described the qualitative risk associated with blade throw, tower failure, rotor delamination, and blade throw strike failures regarding wind turbine generators.
- 2022 | California | Provided owner's engineering support for a wind repower project. Completed a load flow study and reactive power study.
- 2021 | 60 MW | California | Provided owner's engineering services to support the development of the project's full repower. Work included conceptual design support for the collection system and associated overhead line. Also provided EPC contracting support.
- 2021 | 300 MW | Illinois | Performed asset acquisition due diligence reviews. Scope of review included the wind turbine foundations, roadway civil design, and electrical balance-of-plant design. Created a fatal flaw letter report to support the owner during the acquisition process.
- 2020–2021 | 170 MW | Texas | Performed a desktop environmental and permitting review to establish a permitting matrix for the partial repower wind project. The matrix included provisions for pursuing a partial repower and full repower scenario. Also provided cost estimates and timelines for the permitting effort.
- 2019–2021 | Texas | Performed a review of a single wind turbine foundation that experienced an impact when a rotor, blades, and gear box detached from the nacelle and fell to the ground. Performed a desktop review of the design, a detailed foundation loading analysis, and an impact structural analysis of the foundation. Developed a scope of work based on the results for the strategic subgrade excavation of the foundation to observe any damage resulting from the impact.
Performed a site visit and provided a detailed summary of the condition of the foundation, identified potential risks and areas of concern, and recommended remediations to the foundation.

- 2020 | 97 MW | Argentina | Interviewed the project’s substation engineering company and visited the site to assess construction and grid connection progress. Opined on the completion status of documentation and construction works and recommended steps to expedite completion. Subsequently prepared a letter report summarizing project status, including recommendations for completion.

- 2019 | Supported the European Bank for Reconstruction and Development (EBRD) and the Ministry of Energy of a country in eastern Europe in developing new renewable energy resources (wind and solar PV). Scope included evaluating and selecting sites for future renewable generation, developing a detailed framework for a competitive bidding process (auction), developing auction rules, recommending institutional and financial arrangements (to support the bids selected during the competitive bidding process), and advising on the financial and technical considerations associated with the auctions. Also evaluated the different bids that were submitted to the auction, responded to bidders’ questions, and short-listed the total number of bidders.

- 2018–2019 | Hawaii | Conducted owner’s engineering reviews and support of a new wind project. Scope included a review and negotiation of key project agreements such as the turbine supply agreement, BOP EPC agreement, and O&M agreement.

- 2018 | Southwestern United States | Advised client—who was to assume ownership of wind project under a build-transfer arrangement—on several aspects of the project development, including wind resource, turbine layout, and O&M contract arrangements.

- 2018 | United States | Performed project siting on behalf of a client looking to develop a wind project. Scope included exploring various options across the United States and adhering to a set of parameters outlined by the client.

- 2018 | Performed a wind project O&M cost and performance benchmarking study for a large US wind owner-operator.

**Herling Construction Inc.**

2022 | 160 MW | Texas | Brazos Wind Farm | Performed a WTG felling analysis considering the “cut and fell” method for 160 existing Mitsubishi 1000 wind turbines. Used finite element modeling in SAP2000 to confirm that the towers would remain stable under certain wind conditions as well as the maximum expected tension in a steel cable required to pull the tower over. Confirmed the conditions for which the turbines were analyzed and the limiting site conditions to be considered during felling.

**Leeward Renewable Energy, LLC**

- 2021–2023 | 54 MW | Illinois | Crescent Ridge I Wind Project | Contracted SOS to perform structural health monitoring for three wind turbines at the project site, then post-processed the data to confirm the current foundation stiffness and other parameters ahead of the scheduled repower. Subsequently issued a letter summarizing the results of the analysis. Prepared a work specification outlining critical requirements for the contractor and reanalyzed the foundations to ensure the
appropriate anchors and design limitations were considered in the final work specification. Reviewed monitoring data and determined the rotational stiffness for typical wind conditions at the site. Designed an unreinforced concrete collar to be installed at the foundations at which the soil stiffness was a concern and movement was indicated by the soil conditions.

- 2022 | 322 MW | Texas | Sweetwater Wind Project | Provided owner's engineering services to perform a fatal flaw review. Provide an opinion on whether the foundations were likely to be able to be used as-is or if they required a retrofit. The sites were as follows:
  - 241 MW | Sweetwater 4
  - 81 MW | Sweetwater 5
- 2022 | 80 MW | Pennsylvania | Allegheny Ridge Wind Project | Performed a fatal flaw review to comment upon whether project foundations could be reused or would require a retrofit. Determined the increase in overturning moment from the new WTG platform, as documented in the foundation load specifications, then reviewed the existing calculations to determine whether any margin was available in the design such that the existing foundation could accommodate the expected moment increase.
- 2022 | 50 MW | California | Kumeyaay Wind Project | Performed a fatal flaw review to comment upon whether project foundations could be reused or would require a retrofit. Determined the increase in overturning moment from the new WTG platform, as documented in the foundation load specifications, then reviewed the existing calculations to determine whether any margin was available in the design such that the existing foundation could accommodate the expected moment increase. In this case, results indicated that extensive remediation would likely be required.
- 2021–2022 | 80 MW | Illinois | GSG Wind Project | Evaluated the reuse of the existing collection system. Support included performing a collection system ampacity study, a short-circuit study, and a wind turbine grounding study. Performed wind turbine foundation analyses and preliminary foundation retrofit designs. Provided a wind turbine removal analysis of 40 Gamesa G-87 turbines to support decommissioning of the existing project. Considered two standard removal strategies: "cut and fell" and "energetic" methods. Provided expert testimony for the zoning board. Provided ongoing owner's engineering support as the client worked towards planning the repower project. Provided high-level calculations to approximate the overall size of wind turbine foundations that would be required to be designed to replace the existing foundations. Provided a range of overall estimated foundation dimensions for planning and initial estimating purposes.
- 2021–2022 | 144 MW | New Mexico | Aragonne Wind Project | Reviewed the concrete pours for three specific foundations in support of repower due to potential nonconformance during installation. Scope included a review of quality control documentation for pours, data logs, site notes, concrete compressive strength testing, and mix composition.
- 2020 | 80 MW | Illinois | GSG Wind Project | Performed a high-level fatal flaw review of existing wind turbine foundations to opine on whether the existing foundations are suitable for reuse as part of a repower project.
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Qualifications and Experience
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Na Pua Makani Power Partners, LLC

2020–2022 | 27.6 MW | Hawaii | Na Pua Makani Wind Project | Provided miscellaneous technical advisory services to review cracks in the ground surrounding the foundations for two wind turbines. Provided recommendations for next steps and potential remediation.

Northland Power Inc.

2022 | 108 MW | New York | Ball Hill Wind Farm | Provided a full-time onsite civil and structural quality specialist to provide construction oversight of the wind turbine foundations installation. Performed quality checking of the excavations, concrete pours, rebar placement, and backfilling of all 25 wind turbine foundations. Provided field reports for all foundation-related activities.

Orsted Onshore Development North America, LLC

2020–2022 | 200 MW | Texas | Helena Wind Project | Provided owner's engineering support for a 200-MW wind project that is co-located with a utility-scale solar project, for which work has also been performed as an owner's engineer. Project scope included EPC submittal reviews for the civil, wind turbine foundations, collection system, and substation for the project.

Northern Indiana Public Service Company

2020–2022 | 300 MW | Indiana | Indiana Crossroads Wind Farm | Supported detailed design package reviews, reviewed major project contracts (turbine supply, EPC, and O&M agreements), and monitored construction through site visits and desktop reviews of project quality control documentation.

Perennial Power Holdings, Inc.

2022 | 211.2 MW | Texas | Mesquite Creek Wind Project | Performed a wind project operational performance assessment for an operating utility-scale wind project. Scope included a historical performance assessment and an operations and maintenance review to assess the ability of the project to achieve availability targets in the future. Review included a site visit to observe the condition of the equipment and facilities.

PNE USA, Inc.

2022 | 169.2 MW | Oklahoma | Chilocco Wind Farm | Reviewed the existing scopes of work provided by the EPC contractor and turbine supplier, compared them to the specification, and identified variations. Reviewed the updated proposals by the EPC contractor and turbine supplier for incorporation of items identified. Assisted the client in the development of a high-level execution schedule for the project, including the major milestones from both the EPC and turbine supply scopes of work.

Potenita Renewables, Inc.

2022 | Supported the client in expanding their existing civil/structural technical specification. Reviewed the existing specification and made updates to the existing documents based on industry experience and code requirements.
Power County Wind Parks

2020 | 300 MW | Oklahoma | Balko Wind Project | Performed a wind turbine foundation analysis and electrical BOP fatal flaw review in support of feasibility determination for partial repowering. Project was not completed, as foundation analysis results demonstrated that the foundations required retrofitting to be used for partial repower.

Power Plant Management Services, LLC

2022 | 132 MW | Texas | Sherbino Mesa II Wind Project | Assessed the impact on the project from configuration and operational changes expected at another facility that the project shares certain interconnection systems. Conducted a load flow screening study, an electrical design review, and a commercial operations review.

PSEG Long Island

2017 | Assisted with the evaluation and selection of bids submitted under terms of RFPs for the South Fork “Reforming the Energy Vision” project, which includes offshore wind. Developed evaluation models, handled bid administration, performed quantitative and qualitative technical, economic, and financial analyses of bids, and provided recommendations for stakeholder decision-making.

Vientos Los Hercules S.A.

2020 | 97.2 MW | Argentina | Vientos Los Hercules Wind Project | Performed an audit of the substation design and the engineering progress at a wind power project located in Argentina. The following tasks were performed: (i) reviewed the master deliverable list for the substation design and engineering; (ii) verified the status and priority of design documents; (iii) interviewed site personnel to assess their understanding of design and engineering management; and (iv) performed a site visit to review the substation construction status as well as the conditions of equipment stored at the site.

Additional Project Experience

American Capital Energy & Infrastructure

2014–2016 | 150 MW | Senegal | Taiba Wind Project | Support project development as owner’s engineer.

BBVA Securities

2010 | Nova Scotia, Canada | Glen Dhu Wind Project | Developed a pro forma financial model for the project lenders to support financing.

City of New Ulm

2008–2009 | Minnesota | Coordinated and managed the development of a small wind energy project. Scope included feasibility studies, contract development, and wind turbine selection.
Confidential Clients

- 2015–2018 | Performed numerous wind project decommissioning projects for various clients. Services included preparing decommissioning plans and cost estimates, conducting an environmental review, and overseeing decommissioning.
- 2015 | Kenya | Provided a wind resource assessment and site evaluation for a wind project.

Energía Eólica de Honduras, S.A.

2009 | 100.5 MW | Honduras | Supported the development and implementation of a wind project. Reviewed the client’s draft BOP agreement and developed exhibits for the agreement, including the contractor’s scope of work, technical specifications for all BOP components and systems, and completion criteria for all major systems and stages of construction.

E.ON Climate & Renewables

- 2008–2009 | Stony Creek Wind Project | Provided geotechnical and structural design consulting to guide the client in selecting the optimal wind turbine foundation.
- 2008 | Panther Creek, Inadale, & Pyron Wind Projects | Provided consulting and BOP design review services to support development and implementation.

Gestamp Wind North America

2009 | Midwestern United States | Supplied interconnection advisory services and prepared interconnection request forms—including wind turbine technical information and a one-line diagram—for the client’s project under development.

Half Moon Power

2008–2009 | Midwestern United States | Support the development and implementation of multiple projects. Services included conceptual project siting and layout and the preparation of interconnection requests.

Lincoln Clean Energy

- 2017 | 500 MW | Texas | Calculated a decommissioning cost estimate of two wind projects.
- 2017 | 250 MW | Texas | Supported operational readiness—particularly by developing O&M procedures—for a wind project.

Mainstream Renewable Power

2010 | Illinois | Provided consulting and owner’s engineering services to support the development and implementation of a wind project. Provided advisory services for negotiation of the interconnection agreement and performed the transmission power flow study.
REpower USA (now Senvion)

2008 | Washington | Windy Point Wind Project | Evaluated the wind turbine foundation design for Phase 1 of the project. The facility uses the P&H-type foundation design.

Third Planet Windpower

2008–2009 | 100 MW | Loraine Windpark Project | Assisted with EPC contractor oversight during construction. Also evaluated nonconformances.
Conceptual Design and Studies

Selected Recent Project Experience

Acciona Energy USA Global

2018–2019 | Texas | Palmas Altas Wind Farm | Conducted a design review on the wind turbine foundation.

Apex Clean Energy

- 2019 | Northeastern United States | Supplied engineering and design services for wind turbine foundations for a planned large wind farm.
- 2019 | 297 MW | Ohio | Emerson Creek Wind Farm | Supplied engineering and design services for a 345/34.5-kV collector substation, 34.5-kV collection system, and 345-kV transmission line.
- 2018–2019 | 302 MW | Illinois | Lincoln Land Wind Farm | Supplied engineering and design services for a 345/34.5-kV collector substation and 34.5-kV collection system.

Avangrid Renewables (formerly Iberdrola Renewables)

2018–2019 | Illinois | Midland Wind Farm | Prepared a 30% design package for bidding purposes for the 34.5-kV collection system, 34.5-kV collection substation, and 138-kV transmission line.

Calpine

2019 | 124 MW | New York | Bluestone Wind Farm | Supplied engineering and design services for the 115/34.5-kV collector substation, 115-kV interconnection switchyard, and 115-kV transmission line tap.

Confidential Clients

- 2022–2023 | Reviewed four geotechnical reports for four potential wind power project sites. Reviewed soil borings, selected soil testing, groundwater levels, geotechnical parameters (shear strength and bearing strength), site classification, and geologic and geotechnical site hazards, including but not limited to slope stability concerns, liquefaction potential, shrink and swell potential, and collapse potential. Provided quantitative assessments of site suitability for the utilization of collared-pier wind turbine foundations.
- 2022–2023 | Evaluated the interconnection of a wind and solar facility for an interconnection queue.
- 2022 | Performed additional field measurements of existing WTG steel towers at the project site to supplement as-built dimensions of the towers. Developed a standardized process, which incorporated lessons learned and best practices, for the collection of similar data on other projects. Prepared a drawing set showing the dimensional information that was previously collected.
- 2022 | Performed field measurements of existing WTG steel towers at the project site to complete a tower structure design data standard form. Prepared a data form outlining the dimensions.
2018–2022 | Provided up-front development support for a portfolio of wind assets. Performed site identification, GIS modeling, desktop geotechnical studies, desktop turbine transportation studies, interconnection support, turbine technology evaluations, and wind energy production estimates. Support also included desktop environmental and permitting support.

2022 | Performed a mock system impact study for an interconnection project. Reviewed the queue models and queue projects in the area of the project that were removed from the models. Determined potential necessary network upgrades and cost allocation estimates based on PJM’s previous cost estimates for the upgrades.

2022 | Performed system impact studies based on the latest revision of system impact study models that included light load and sensitivity analysis. Determined potential necessary network upgrades and cost allocation estimates based on previous cost estimates for those upgrades.

2021–2022 | United States | Performed PJM mock system impact studies for certain wind projects in the PJM queue. Performed a deliverability analysis of the summer peak case to determine overloads caused by or attributed to the projects. Documented the noted overloads and assessed likely upgrades. Also performed a light load analysis for the wind projects.

2021–2022 | Performed a system impact study based on current interconnection queue conditions. Identified any adverse reliability impacts caused by the addition of the project as well as any required system upgrades to mitigate these impacts.

2021–2022 | Performed a system impact study of a project in the PJM queue and approximated the results of the in-progress official PJM system impact study re-tool. Scope included evaluations of thermal impacts on the peak summer case as well as the identification of potentially necessary system reinforcements.

2019 | Azerbaijan | Performed a LCOE analysis for wind project development. Used regional projects with known cost and performance data as proxies.

Invenergy

2019 | 208 MW | Canisteo Wind Farm | Provided engineering and design services for 115-kV interconnection switchyard upgrades.

NextEra Energy Resources

2018–2021 | 44 MW | Pennsylvania | Waymart II Wind Farm | Provided engineering and design services for the 34.5-kV, 15-mile overhead collection lines.

2018–2019 | 250 MW | Oklahoma | Skeleton Creek Wind Farm | Provided engineering and design services for the 345/34.5-kV collector substation and 30-mile, 345-kV transmission line.

2018–2020 | 600 MW | Kansas | Soldier Creek Wind Farm | Provided engineering and design services for the 345/34.5-kV collector substation and 80-mile, 345-kV transmission lines.

2018–2020 | 200 MW | Texas | Hubbard Wind Farm | Provided engineering and design services for the 345/34.5-kV collector substation and 20-mile, 345-kV transmission lines.
UKA North American

2018–2019 | Illinois | Midland Wind Farm | Prepared a 30% design package for bidding purposes for the 34.5-kV collection system, 34.5-kV collection substation, and 138-kV transmission line.

Additional Project Experience

Acciona Energy USA Global

2008 | 100 MW | Ecogrove Project | Provided engineering and design services for the 138/34-kV collector substation as a subcontractor to the Morse Group. Provided engineering and design upgrades at six remote-end substations to support the interconnection, and provided commissioning, testing, and quality control services for the collector substation and 138-kV interconnection transmission line.

BP Wind Energy

- 2010–2011 | 147.5 MW | Texas | Sherbino Mesa II Wind Project | Provided engineering and design services for one 138/34.5-kV collector substation, one 138-kV junction substation, a 138-kV transmission line, and a 34.5-kV collection system.
- 2010–2011 | 225 MW | Texas | Trinity Hills Wind Project | Provided engineering and design services for one 345/34.5-kV collector substation, a 345-kV transmission line, and a 34.5-kV collection system.
- 2009 | Central United States | Conducted a transmission power flow study to support operation of the client’s wind energy project.
- 2008–2009 | Pennsylvania & Virginias | Developed conceptual one-line diagrams and data required for the system impact and feasibility studies for five wind projects.

Confidential Client

2009 | Conceptual design and study for integrating energy storage with the client’s wind energy project.

Cherokee Nation

2008 | Assessed a wind energy project’s feasibility white paper.

EDP Renewables

- 2015–2016 | 78.8 MW | New York | Arkwright Summit Wind Farm | Performed engineering and design services for the 115/34.5-kV collector substation, 115-kV transmission line, and 34.5-kV collection system.
- 2015–2016 | 250 MW | Texas | Hidalgo Wind Farm | Provided engineering and design services for the 345/34.5-kV collector substation, 345-kV transmission line, and 34.5-kV collection system.
Electric Power Research Institute

2010: 2015–2020 | Global | Provided EPRI with annual updates to the client’s *Wind Power Technology Guide*. Updates included capital cost estimates, O&M cost estimates, and performance data for sites in the United States and several international locations for both onshore and offshore wind. Also conducted LCOE calculations and sensitivities.

Enel Green Power North America

2017–2018 | 250 MW | Illinois | HillTopper Wind Farm | Provided engineering and design services for the 345-kV interconnection switchyard.

Gamesa Energy

2010 | United States | Gamesa Wind Project | Conducted an investigation and assessed an electrical failure. Issued findings and recommendations to correct the issue and prevent reoccurrence.

Goldwind USA

2011–2012 | 108 MW | Illinois | Shady Oaks Wind Farm | Provided engineering and design services for the 138/34.5-kV collector substation and 138-kV interconnection switchyard.

Maui Electric Company

2013 | Performed a renewable energy integration assessment to assist the client with their efforts to expand the use of wind and solar power while maintaining reliability requirements.

Noble Environmental Power

2008–2009 | 350 MW | Texas | Prepared conceptual one-line diagrams and general arrangement drawings. Supported client in discussions with the transmission system operator for a wind park.

Xcel Energy

- 2016 | 100 MW | Minnesota | Stone Ray Wind Farm | Performed engineering and design services for the 34.5-kV interconnection substation’s expansion.
- 2016 | 200 MW | Minnesota | Red Pine Wind Farm | Provided engineering and design services for the 345-kV interconnection substation (Hawks Nest Lake Substation) and modification of the 345-kV interconnection transmission line.
- 2015 | 150 MW | North Dakota | Border Wind Farm | Engineering and design services for the 230-kV interconnection substation (Peace Garden Substation) and modification of the 230-kV interconnection transmission line.
Renewable Energy and Energy Storage
Qualifications and Experience
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Construction Monitoring/Management

Selected Recent Project Experience

Acciona Energy USA Global

Altamont Winds
2019 | 58 MW | California | Summit Wind Project | Provided construction management and owner’s engineering services to support development, engineering, and construction.

NextEra Energy Resources
2017–2018 | Supplied independent construction oversight for numerous wind projects during repowering.

Additional Project Experience

AES
2009 | Pennsylvania | Armenia Mountain Wind Project | Oversaw construction on behalf of the project lenders to support financing. The facility uses GE 1.5sle WTGs.

BBVA Securities
2010–2011 | Nova Scotia, Canada | Glen Dhu Wind Project | Oversaw construction on behalf of the project lenders to support financing.

BP Wind Energy

- 2010 | 124.5 MW | Idaho | Goshen II Wind Project | Provided independent construction oversight on behalf of the project lenders to support financing.
- 2008 | 301.3 MW | Indiana | Fowler Ridge Wind Project | Provided onsite construction management and commissioning services.

CG Power
2011 | Idaho | Power County Wind Farm | Provided independent construction oversight.

ContourGlobal
2013–2014 | 114 MW | Peru | Provided independent construction oversight of a wind project on behalf of bond financing arrangers.
Eco Energy/Acciona

2008 | Provided commissioning, testing, and quality inspection services for a 138-kV transmission line and 138/34.5-kV substation as a subcontractor to Morse Electric.

EDP Renewables

- 2008–2009 | Top Crop Project | Developed operating procedures for the Phases 1 and 2 interconnection and collector substations.
- 2007–2008 | Twin Groves Project | Provided construction management and performed electrical testing and commissioning for the substation and transmission lines for Phases 1 and 2.

NextEra Energy Resources

2012 | Michigan | Tuscola Bay Wind Project | Supplied independent construction oversight on behalf of project lenders to support financing.

Third Planet Windpower

2008–2010 | 100 MW | Texas | Loraine Windpark Project | Certified Phase I of project completion. Also supplied onsite construction management and commissioning services.

U.S. International Development Finance Corporation (formerly Overseas Private Investment Corporation)

- 2016–2018 | 50 MW | Hawa Wind Project | Acted as lender’s technical advisor for construction monitoring.
Operations and Maintenance Support and Services

Selected Recent Project Experience

BP Wind Energy
2011–2018 | 124.5 MW | Idaho | Goshen II Wind Project | Conducted independent engineering annual O&M assessments and budget reviews.

Patrick & Henderson
2018–2019 | Conducted post-processing of the wind turbine tower and foundation sensor data for the wind turbines at Desert Sky Wind Farm, Trent Mesa Wind Farm, Snyder Wind, and Auwahi Wind.

Confidential Clients

- 2021 | Performed an assessment of wind power O&M costs and performance. Scope included the project EAF for the entire dataset as well as O&M costs: (i) by project age; (ii) by owner and owner fleet size; (iii) by project regulatory market environment; (iv) by wind turbine original equipment manufacturer; (v) by subcategories; and (vi) by regional differences.
- 2018 | Performed an O&M cost and performance analysis of a large dataset from 78 operating wind projects with over 142 operating years of information. Identified patterns and trends about O&M costs with respect to project age, size, O&M approach, turbine manufacturer, and location.
- 2015–2018 | Performed numerous decommissioning projects for various clients. Services included preparing decommissioning plans, calculating decommissioning cost estimates, and providing decommissioning field oversight.
- 2017 | 350 MW | Kansas | Calculated O&M projections on two wind projects.

Herling Construction Inc.
2018 | Illinois & Texas | Performed a WTG decommissioning analysis for the Gulf Wind Farm (Texas) and Mendota Hills (Illinois).

Lincoln Clean Energy LLC
2017 | Texas | Performed decommissioning cost studies for the Willow Springs Wind Farm and Dermott Wind Farm.

U.S. International Development Finance Corporation (formerly Overseas Private Investment Corporation)
2017–2019 | 50 MW | Pakistan | Master Wind Project | Monitored operations.
Additional Project Experience

Confidential Clients

- 2015–2016 | West Virginia | Reviewed wind turbine foundations at an operating wind power project to assess potential remediation options.
- 2015 | Midwestern United States | Reviewed wind turbine foundations at an operating wind project. Performed design calculations to assess the suitability of the original design.
- 2011 | Western United States | Performed a third-party failure analysis of wind turbine blade failures for a project.
- 2010 | Engaged by an investment firm to perform technical due diligence on a wind O&M services company that the client was seeking to acquire. Evaluated the target firm’s vibration monitoring technology and provided assessments and recommendations regarding the effectiveness and market potential of the technology.
- 2009–2010 | Provided technical support for negotiations with a wind turbine supplier to resolve a serial defect with critical wind turbine components.

BP Wind Energy

2010 | Engaged to develop a wind turbine foundation inspection guideline for the client’s O&M personnel to use during their annual inspections and maintenance. Developed guidelines based on extensive knowledge and experience with the design and operating considerations for wind turbine foundations.

Enel Green Power North America

2010 | New York | Assessed the causes of a wind turbine collapse: one 1.5-MW turbine collapsed after 10 years of operation. Also provided design input for the revised foundation design and remediation plan; subsequently, performed independent engineering reviews of the revised design.

NextEra Energy Resources

2010 | Langdon Wind Project | Reviewed plant performance, turbine reliability, and O&M procedures and practices on behalf of the project lenders. Assessed the need for O&M budget and maintenance reserve adjustments based on the initial two years of plant performance.
Offshore Wind

Selected Recent Project Experience

Confidential Clients


Equinor

- 2020–2021 | New York | Empire Wind | Performed a reactive power study as part of Phase 1 to verify that the ConEd power factor requirements were met.


- 2020 | New York & New Jersey | Prepared electrical system design studies to support bids in response to the New York and New Jersey offshore wind solicitations. These studies established conceptual designs of overall plant electrical systems and interconnection schemes.

- 2019 | New York | Empire Wind | Performed contingency load flow analyses to evaluate potential alternative points of interconnection for Phase 1.

- 2018–2019 | New York | Conducted a system reliability impact study to support the client’s bid in response to the New York offshore wind solicitation.

PSEG Long Island

- 2017–2021 | 90 MW | Sargent & Lundy is monitoring the project development of the South Fork Offshore Wind Project, on behalf of the power purchaser. Our monitoring role will continue throughout construction and commissioning.

- 2015–2017 | 90 MW | Sargent & Lundy provided consulting services to support the selection and development of a planned offshore wind project. We reviewed the technical and economic feasibility of the offshore wind project and helped our client negotiate a PPA with the wind project developer. Sargent & Lundy is monitoring the project development and will monitor the project construction.
Additional Project Experience

NRG

2010–2011 | 450 MW | Mid-Atlantic Wind Park | Provided conceptual engineering services for the landfall and underground portions of the 230-kV transmission line interconnection, including route evaluation, landfall and duct bank engineering, and permitting support. The transmission line design had two circuits, each serving half of the project. Client did not proceed with the project.
Solar Power

Sargent & Lundy has significant solar project experience and is on the forefront of new solar technologies and applications—from bifacial PV modules to the integration of solar and battery energy storage. We were the BOP engineer for the design of the SEGS VIII, IX, and X facilities in the late 1980s and have been active in the development of solar energy ever since. Our activity in the renewable energy generation market includes owner’s engineering, technical due diligence, and conceptual design services on behalf of our clients.

The following pages list some of our most recent solar experience.
Due Diligence & Independent Engineering

Selected Recent Project Experience

AES

- 2019–2022 | 100 MW (each) | El Salvador | Bosforo II & Bosforo III | Performed technical due diligence. Assessed key technical, financial, commercial, environmental, and social risks associated with the development, financing, implementation, construction, and operation of the projects.
- 2016–2022 | 100 MW | El Salvador | Bosforo I | Assessed the key technical, financial, commercial, environmental, and social risks associated with the development, financing, implementation, construction, and operation of the project. Served as an independent engineer.

American Electric Power

- 2018 | Nevada | Boulder II Project | Performed an end-of-warranty inspection. Work included reviewing the general arrangements for the project to develop a site-specific inspection plan with the intent of reasonably identifying EPC warranty items based on visual observation.
- 2018 | Utah | Pavant III Project | Performed an end-of-warranty inspection. Work included reviewing the general arrangements for the project to develop a site-specific inspection plan with the intent of reasonably identifying EPC warranty items based on visual observation.

BELECTRIC GmbH

2018 | North Carolina | Provided due diligence services.

Borrego Solar

2019 | 8 MW | Illinois | Provided interconnection support for four 2-MW PV projects. Reviewed the lottery combined study reports issued by ComEd to assess the proposed costs and identify potential areas where the scope of upgrades may be reduced.

Community Power Group

2019 | Illinois | Supported an interconnection application for a PV project.

Confidential Clients

- 2022 | Prepared a decommissioning plan and cost estimate. The decommissioning plan covered the anticipated life of the facility, the way the facility will be decommissioned, and demolition and remediation estimates. Developed the decommissioning plan in accordance with state, local, and project-specific requirements.
• 2022 | Performed an independent review of a new solar PV racking system to detect any technological risks that could impact the client's ability to finance a project. Worked directly with the vendor to better understand the system and future development plans.

• 2022 | 550 MW | Pennsylvania & Virginia | Performed due diligence work on a portfolio of solar PV projects in Virginia and Pennsylvania with a focus on interconnection status. Assessed and commented on the status of the projects in the interconnection queue process. Also identified risks and provided recommendations.

• 2022 | 207 MW | Indiana | Prepared a decommissioning plan and cost estimate. The decommissioning plan covered the anticipated life of the facility, the manner in which the facility will be decommissioned, and demolition and remediation estimates. Also developed the decommissioning plan in accordance with state, local, and project-specific requirements.

• 2021–2022 | Reviewed bids to supply power conversion systems for conversion of DC power from solar PV arrays to medium-voltage AC collector systems.

• 2021–2022 | Provided independent engineering services to support solar PV due diligence requests. Performed a site visit to a distributed generation solar facility and performed PVsyst energy yield assessments.

• 2021–2022 | Performed an independent engineering review of a new residential solar company that will provide residential solar financing opportunities. Provided an opinion on the technical aspects of the company's residential solar and solar-plus-storage projects and identified any perceived risks related to future performance.

• 2021 | 1 GW | Connecticut, Georgia, Nevada, & Tennessee | Provided an independent engineering opinion and evaluation of the ability of six projects to achieve a 35-year operating life. Support included detailed component margin evaluations for the modules, racking, inverters, collection system, substation, and transmission line of each project. Reviews also included operational recommendations for achieving the desired operating life.

• 2021 | 600 MW | Illinois | Modified two existing interconnection applications already in the PJM queue. The change for each was a different inverter. The revised application was supplied to PJM for studying the requests and determining whether they are deemed a material modification.

• 2021 | 150 MW | Michigan | Provided technical assistance regarding the move of a POI for a 2019 MISO queue project. Performed a cost benefit analysis, thermal and voltage analysis, dynamic stability analysis, and short-circuit analysis to assess whether the POI change would have an adverse impact on the transmission system and thus be considered a material change.

• 2021 | 150 MW | Tennessee | Served as independent engineer in support of tax equity investors for a solar project. Support included construction monitoring, technology and design reviews, an independent energy yield assessment, and commercial, permitting, and financial model reviews.

• 2021 | 250 MW | Nevada | Served as independent engineer in support of tax equity investors for a 200-MW solar + 50 MW/4-hour AC-coupled storage project. The support included construction monitoring, technology and design reviews, an independent energy yield assessment, and commercial, permitting, and financial model reviews.
- 2020–2021 | Provided technical advisory services to support the development of a new solar PV tracker concept. Services included bankability reviews of the solar tracker design. Also provided general technical advisory support to address a bankable tracker concept.

- 2020 | 20 MW | Jamaica | Served as independent engineer for a solar PV project for refinancing. Services included an independent solar energy yield assessment, technical due diligence in support of funding, construction monitoring, and operations monitoring.

- 2020 | 150 MW | Provided independent engineering services in support of tax equity financing of a solar PV project in Texas. The support includes construction monitoring, technology and design reviews, an independent energy yield assessment, and commercial, permitting, and financial model reviews.

- 2020 | Performed PV tracker bankability reviews in support of a tracker vendor.

- 2020 | Provided a Level 5 cost estimate of a PV project considering a managed-EPC project structure. Cost estimate was broken down into the cost for various contractor-specific tasks.

- 2020 | Provided a Level 4 cost estimate of a PV project in development based on layout drawings and site-specific material totals. Estimate used a parametric model to utilize material quantities and installation hours and rates for specific components.

- 2018 | Performed asset evaluations of seven projects for potential acquisition. Projects included one wind project, one CSP project, and five solar PV projects.

**Content Solar Limited**

2021–2022 | 20 MW | Jamaica | Monitored construction and operations and performed construction completion reviews. Additionally, reviewed each borrower’s drawdown requests. Once issues were resolved, approved each drawdown certificate.

**CS Energy**

2021–2022 | 150 MW | New York | Yellow Barn Solar Energy Facility | Developed a bankable solar resource assessment and energy yield. Support included a solar resource database comparison and a selection between multiple bankable vendors. The energy yield support included detailed a soiling loss, albedo calculation, and PVsyst modeling review.

**Desert Sunlight 250, LLC**

2022 | 230 MW/920 MWh | California | Desert Sunlight | Performed an independent engineering review for a solar PV and BESS project. Provided a high-level description of the large generator interconnection agreement, shared facility agreement, and the shared facility agreement and large generator interconnection agreement co-tenancy agreements. Assess the programmable logic controller to maintain the large generator interconnection agreement co-tenancy agreements. Assessed the ability of the substation breaker configuration and the overall design of the storage project interconnection.
Domtar Paper Company

2019 | Performed a preliminary screening to assess the feasibility of wind and solar generation at three paper mill locations. Used PVsyst software to produce PV energy yield assessments for each location. Also calculated EPC capital cost estimates.

Ecofin Advisors, LLC

2022 | 78 MW | Ohio & North Dakota | One Energy Portfolio | Evaluated the performance, O&M activities, and resource projections for a portfolio of behind-the-meter wind and solar projects. Also reviewed commercial agreements and advised the client with respect to portfolio acquisition.

Entergy Services, Inc.

2021–2022 | Provided an independent engineering review of scope books as part the RFP process. Reviewed typical scope documents issued by the client as part of RFPs for solar and BESS projects. Identified requirements that exceeded the typical industry standards for financing or deviated from best practices. Provided recommendations for revisions to better establish the scope books as competitive tender documents that maintain a level of specification consistent with Sargent & Lundy’s criteria for similar projects.

FirstCaribbean International Bank

2021 | 47 MW (total) | Jamaica, Cayman Islands, & Guatemala | BMR Energy Portfolio | Provided independent engineering and monitoring services for the refinancing of a portfolio (one wind project and two solar projects). Scope included a performance assessment, site visit, facility assessment, maintenance review, financial review, and environmental, social, health, and safety review.

Hodson Solar, LLC

2021 | 50 MW | Indiana | Jay County | Supported early solar development with a focus on interconnection costs. Work included a cost evaluation for a planned substation. Also conducted desktop studies.

Kyuden International Corporation

2020–2021 | 40 MW | Peru | Majes and Repartición Solar Projects | Performed independent engineering due diligence evaluations of two solar projects under consideration for acquisition. Scope included design, performance, contract, and financial model reviews. Additionally, performed in-person site visits to evaluate proposed panel replacement construction work.

Leeward Renewable Energy, LLC

- 2021–2022 | Texas | Barilla Solar Project | Prepared an interconnection application for a solar PV project for submission to ERCOT. Work included model creation and completion of the required application forms.
• 2019–2020 | Provided independent engineering support throughout the interconnection application process. Scope included the PV layout, yield, single-line diagrams, and CAD drawings.

Mountain Pine Energy

2021–2022 | Virginia | Provided a cost evaluation for interconnection options related to the development of six solar projects that will interconnect with the PJM/Dominion transmission system. Prepared a high-level cost matrix for the possible (theoretical) cases that exist for connecting the solar PV plants to the transmission system; subsequently, recommended specific tie-in configurations for each project.

NextEra Energy Resources, LLC

• 2021–2022 | 22.9 MW | New York | Calverton Solar PV Project | Reviewed key aspects of the project to provide the independent engineer certification required under the power purchase agreement. Reviewed the balance-of-plant designs, technical requirements of the interconnection agreement, construction progress, quality control documentation, and performance testing documentation.

• 2021–2022 | 200 MW | Nevada | Dodge Flat Solar Energy Center |Reviewed and commented upon the relative domestic content value. The project was planned to be an approximately 495-acre facility. Performed an assessment to determine the percent of non-labor content derived from domestic (US) sources relative to the overall project non-labor costs.

• 2020–2022 | United Stated | Central Midway Portfolio | Provided independent engineering due diligence services in support of project financing for a renewable energy portfolio. Assessed the site and construction activities for each project in the portfolio through desktop reviews and site visits. Reviewed the design, selection of major equipment, environmental and permitting efforts, financial performance, and key contracts for each project. Performed independent energy yield assessments. The sites were as follows:
  ▪ 76.5 MW | Maine | Farmington Solar Project
  ▪ 100 MW | Wisconsin | Point Beach Solar
  ▪ 49.5 MW | New Mexico | Route 66 Solar Project

PASH Global

2022 | 94.6 MW | El Salvador and Panama | Real Solar Portfolio | Provided independent engineering technical due diligence services for financing purposes on behalf of the following solar PV projects:

• 25.6 MW | El Salvador | Los Remedios Solar Project
• 14 MW | El Salvador | Sonsonate Solar Project
• 10.4 MW | El Salvador | Trinidad Solar Project
• 7.8 MW | El Salvador | Marquez Solar Project
• 5.1 MW | El Salvador | Rooftop Solar Project
• 3.9 MW | El Salvador | Opico Solar Project
• 1.6 MW | El Salvador | Suno Solar Project
• 1.5 MW | El Salvador | RESU Solar Project
• 1.4 MW | El Salvador | Grupo Roca Solar Project
• 1.4 MW | El Salvador | PVGEN Solar Project
• 1 MW | El Salvador | Alpha Solar Project
• 21 MW | Panama | Pocri Solar Project

SolarReserve/Project Lenders

2018 | 135 MW | Australia | Acted as lender’s technical advisor for a CSP project with molten salt storage in development. Services included independent technical due diligence in support of project financing.

Silk Road Fund

2018 | 700 MW | United Arab Emirates | Supported potential asset investment in a CSP project. Services included independent technical due diligence and presentations on the technology and project.

United States Department of Energy

• 2010–2019 | 100 MW | Nevada | Tonopah Solar Project | Served as independent engineer. Project is a molten salt solar tower project with 10 hours of storage. Services included independent technical due diligence (in support of funding by the client), construction monitoring, and operations monitoring.
• 2010–2019 | 250 MW | California | Mojave Solar Project | Acted as independent engineer. Project is a parabolic trough solar project. Services included independent technical due diligence (in support of funding by the client), construction monitoring, and operations monitoring.

U.S. International Development Finance Corporation (formerly Overseas Private Investment Corporation)

• 2015–2019 | 22.56 MW | El Salvador | REAL El Salvador Solar Project | Acted as the technical advisor for the financing of a collection of solar PV projects in El Salvador. Performed due diligence of the project design, interconnection, commercial agreements, E&S reviews, construction plans, and financial model and energy yield. Performed site visits and fatal flaw reviews in support of project lenders.
• 2015–2019 | 22.56 MW | El Salvador | REAL El Salvador Solar Project | Acted as the technical advisor for the financing of a collection of solar PV projects in El Salvador. Performed due diligence of the project design, interconnection, commercial agreements, construction plans, and financial model and energy yield. Performed construction and operations monitoring as part of this engagement.
2017 | 30 MW | El Salvador | Los Remedios Solar Project | Performed independent engineering consulting services in connection with financing for the development, construction, and operation of two solar PV plants with a combined capacity of 30 MW in El Salvador. Performed a site visit, fatal flaw review, and miscellaneous lender support.

Additional Project Experience

Confidential Clients

- 2017–2019 | 210 MW | Chile | Performed independent technical due diligence and construction monitoring of a project that consists of a 110-MW tower-technology electric power generation thermosolar plant with thermal storage capacity and a 100-MW single-axis tracking PV plant.

- 2017–2018 | Jordan & United Arab Emirates | Reviewed four ground- and roof-mounted solar PV projects and one energy efficiency project on commercial properties to support potential acquisition.

- 2015 | 40 MW | South Africa | Reviewed an operating ground-mounted solar PV project to support potential acquisition.

- 2013 | Arizona | Analyzed the root-cause analyses and corrective actions related to the failures of padmount transformers at a PV solar power plant.

Inter-American Development Bank

- 2015–2016 | 110 MW | Chile | Atacama CSP Project | Served as independent engineer to perform independent technical due diligence and construction monitoring.

- 2015 & 2017 | 100 MW | Chile | Served as independent engineer for a solar PV project with single-axis tracking. Services included an independent due diligence assessment and construction monitoring.

International Finance Corporation

2014–2015 | 70 MW | Philippines | Served as independent engineer for a portfolio of three solar PV projects financed by the client. Services included an independent solar energy yield assessment, technical due diligence in support of funding, and construction monitoring.

SolarReserve/Project Lenders

- 2012–2018 | 100 MW | Africa | Redstone Solar Thermal Power Project | Conducted independent engineering services.

- 2013–2014 | Limestone CSP Project | Provided independent engineering services.
Standard Bank & International Finance Corporation

2011–2017 | 100 MW | South Africa | Redstone CSP Project | Acted as independent engineer. Project is a molten salt solar tower project with 12 hours of storage. Services included independent technical due diligence in support of funding by the consortium of lenders.

Standard Bank of South Africa

- 2011–2012 | South Africa | Conducted independent engineering reviews of proposed solar PV projects. Provided lender’s technical advisory services to support project development and bidding into the South African Renewable Energy Independent Power Producer Program.
- 2011 | 75 MW | Performed independent engineering for a PV solar project. Services included independent technical due diligence in support of funding and construction monitoring.
- 2011 | 50 MW | South Africa | Performed independent engineering for a PV solar project. Services included independent technical due diligence (in support of funding) and construction monitoring.

SunEdison/TerraForm Power

2015 | Canada | Performed asset acquisition due diligence of two solar PV projects to support potential acquisition.

U.S. International Development Finance Corporation (formerly Overseas Private Investment Corporation)

- 2017–2019 | 150 MW | India | Served as independent engineer for a 100-MW solar PV project and a 50-MW solar PV project. Services included an independent solar energy yield assessment, technical due diligence in support of funding, construction monitoring, and performance testing oversight.
- 2016–2019 | 100 MW | El Salvador | Served as independent engineer for a portfolio of solar PV projects. Services included an independent solar energy yield assessment, technical due diligence in support of funding, construction monitoring, and performance testing oversight.
- 2015–2019 | 40 MW | El Salvador | Served as independent engineer for nine solar PV projects. Services included an independent solar energy yield assessment, technical due diligence in support of funding, construction monitoring, and performance testing oversight.
- 2014–2019 | 20 MW | Jamaica | Served as independent engineer for a solar PV project that was financed by the client. Services included an independent solar energy yield assessment, technical due diligence in support of funding, construction monitoring, and operations monitoring.
- 2013–2017 | 5 MW | Tanzania | Served as independent engineer for a solar PV project being financed by the client. Services included technical due diligence in support of funding and construction monitoring.
PV Site Evaluation, Solar Resource, & Energy Production Assessment

Selected Recent Project Experience

**BayWa r.e. USA**

2018 | 12 MW | Michigan | Performed a siting study for 2-MW and 10-MW solar PV plants.

**Borrego Solar, Inc.**

- 2022 | Virginia | Performed an interconnection feasibility study analyses for three proposed solar PV and BESS facilities to be located in PJM territory. The study mimicked a PJM system impact study of the proposed projects and identified likely overloads and potential network upgrades that may be necessary to accommodate the projects. The sites were as follows:
  - 200 MW | Grove Solar
  - 200 MW | Poolesville Storage
  - 200 MW | Chuckatuck Smithfield Storage
- 2022 | New York | Performed interconnection feasibility study analyses for three proposed facilities to be located in NYISO territory. The study mimicked a NYISO feasibility study of the proposed projects and identified likely overloads and potential network upgrades that may be necessary to accommodate the projects. The sites were as follows:
  - 150 MW | Colliers Solar PV
  - 100 MW | Minisink Valley Storage
  - 80 MW | Mt. Hope Storage

**Confidential Clients**

- 2023 | Texas | Performed a preliminary interconnection analysis of a transmission interconnection for a new solar project. Evaluated the injection capability at the stated POI.
- 2022–2023 | Illinois | Performed a mock system impact study to determine potential necessary network upgrades and a cost allocation estimate based on PJM’s previous cost estimates for those upgrades and considering the decrease of project capacity. Validated if the project is the driver for new system upgrades or if the driver is in a prior queue window.
- 2022 | Arkansas | Performed a preliminary interconnection analysis to approximate the available capacity at a substation for interjecting power from a potential solar facility.
- 2022 | Arizona | Performed an injection study for a solar PV project. Also performed a feasibility analysis to evaluate the suitability of the local transmission infrastructure to accommodate the thermal power injection of the proposed generation project. Evaluated the power flow impacts and
identified what, if any, potential network upgrades may be required by the interconnecting utility to accommodate the project’s size.

- **2022 | Colorado** | Performed a material modification analysis and utilized CAPE software to perform an independent breaker duty study to determine if an overrated breaker issue remains.

- **2022 | Illinois** | Performed a mock system impact study and reviewed the queue models and queue projects in the area of the project. Determined potential necessary network upgrades and cost allocation estimates based on previous cost estimates for those upgrades and considering the decreased project capacity.

- **2022 | Texas** | Performed a preliminary interconnection analysis of a transmission interconnection for a new solar project. Evaluated the injection capability at the stated POI and determined the overloads contributed to the projects.

- **2022 | Texas** | Developed an ERCOT interconnection application that included a one-line PSS/E model and PSCAD model for a solar project. Completed a screening study, full interconnection study, and planning model.

- **2022 | Pennsylvania & Virginia** | Performed a system impact study based on the latest revision of the system impact study models supplied by PJM. The system impact study determined potential necessary network upgrades and cost allocation estimates based on PJM’s previous cost estimates for the upgrades.

- **2022 | Illinois** | Performed a system impact study of a project in the PJM queue. Approximated the results of the in-progress, official PJM system impact study. Conducted the system impact study for the base case and sensitivity analysis.

- **2021–2022 | United States** | Performed PJM mock system impact studies for certain solar projects in the PJM queue. Performed a deliverability analysis of the summer peak case to determine overloads caused by or attributed to the projects. Documented the noted overloads and assessed likely upgrades.

- **2021–2022 | California** | Performed a harmonic analysis, a reactive power study, and an evaluation of event data in response to a harmonic resonance condition.

- **2021–2022 | United States** | Investigated and ranked the top 150 POIs between the available voltage levels by estimated available capacity in each region for potential solar and BESS facilities. Evaluated POIs through power flow analyses while using the latest study queue models and support files.

- **2021–2022 | 82 MW & 300 MW | Kentucky & Illinois** | Drafted conceptual site layouts for two projects. Utilized PlantPredict software to develop high-level layouts of the nameplate capacity of each proposed site based on the buildable area. Provided the drawings in .pdf and .kmz formats to the client.

- **2021–2022 | United States** | Performed mock PJM system impact studies for several client projects in the PJM queue by utilizing the TARA module. The primary goal was to identify network upgrades.
Renewable Energy and Energy Storage
Qualifications and Experience
Solar Power — 45

- 2021 | United States | Performed capacity injections on several POIs in different locations throughout the United States. Locations included Arizona, California, and Texas.

- 2020 | New York | Developed tools to assist with the site selection of future PV project locations. Tools allowed the client to filter through 100+ sites ranging from 8 MW to 300 MW. The selection process included comparing their civil feasibility, ease of interconnection, PV performance, and site-specific costs.

- 2019 | 1.5 GW | Abu Dhabi | Provided bid support for a leading developer/IPP for the recent 1.5-GW solar project tender. Performed an independent energy yield assessment based on a single-axis tracking project using bifacial solar modules. Considered solar field layout optimization opportunities and the integration of battery energy storage.


- 2018 | 8 MW | Caribbean | Developed a conceptual layout and energy estimates for an solar PV project being developed on a Caribbean island. Evaluated fixed-tilt and single-axis tracking configurations as well as thin-film and crystalline PV module options. Also prepared cost estimates.

HGD Energy LLC

2021–2022 | 40 MW | Ohio | Bellefontaine Solar Project | Provided engineering services related to the right-of-way development for a transmission line from the project site to a 138-kV substation. Performed a two-phase approach with Phase 1 focused on the preparation of documentation to commence the permitting process and Phase 2 focused on documentation and engineering support for issuance of permits for railroad crossing and interconnection at the substation.

HSE Foundation Solar, LLC

2021–2022 | 90 MW | Pennsylvania | Turnpike Solar Project | Performed a mock system impact study of the 90-MW Turnpike Solar project in the PJM interconnection queue that is proposed to interconnect into the PENELEC transmission system. Also provided high-level cost estimates for the expected upgrades.

M3 Builders, LLC

2021–2022 | 50 MW | Arizona | Gila Bend Solar Project | Prepared inputs for project development and planning. Scope included a conceptual layout and corresponding energy model. Specifically, analyzed the project-specific nameplate capacity in consideration of the land area available and the expected energy output.

PNE USA, Inc.

- 2022 | 50 MW | Pennsylvania | Mountain City Solar Project | Performed a mock system impact study for the project, which was to be submitted into the PJM AH2 queue cluster. The project proposed to interconnect into a 69-kV transmission line on the north boundary of the project site. The injection
study identified the thermal capacity available on the circuit prior to triggering a potentially cost-allocated network upgrade.

- 2022 | 50 MW | Illinois | Kishwaukee Solar Project | Performed a mock system impact study of a prospective project. The injection study identified the thermal capacity available on the circuit prior to triggering a potentially cost-allocated network upgrade.

- 2022 | Developed a scope of work for two large generator interconnection applications for two solar and battery storage projects. Prepared a single-line diagram and various models (e.g., power flow and dynamics model, generic dynamics model, ASPEN short-circuit model of the facility, and EMT model of the facility). Prepared the FERC large generator interconnection application form. The sites were as follows:
  - 150 MW + 75-MW BESS | Idaho | Market Lake
  - 150 MW + 75-MW BESS | Utah | Red Butte

**Stella Energy Solutions LLC**

2023 | Evaluated two prospective layouts for a solar project with a cooperative utility. Provided recommendations as to which layout will provide more production during the afternoon hours.

**Township of Sparta**

2021 | 5 MW | New Jersey | Supported a small generator interconnection application and an application for a solar PV facility. Prepared feasibility study and system impact study forms. Drafted a preliminary system one-line for part of the interconnection process. Provided a generic model for use by PJM to perform the system impact study. Additionally, initiated a grid supply solar application. Developed a preliminary site layout using Plant Predict software as part of the application process.

**U.S. International Development Finance Corporation (formerly Overseas Private Investment Corporation)**

- 2016–2019 | 100 MW | El Salvador | Performed independent solar resource and energy production assessments of a solar PV project to support project financing.

- 2015–2019 | 40 MW total | El Salvador | Performed independent solar resource and energy production assessments of nine solar PV projects to support project financing.

- 2014–2019 | 20 MW | Jamaica | Served as independent engineer for a solar PV project that was financed by the client. Services included an independent solar energy yield assessment, technical due diligence in support of funding, operations monitoring, and construction monitoring.

**Vistra Energy**

2017–2018 | 180 MW | Texas | Performed energy yield studies as part of an evaluation to add battery energy storage to the existing Upton 2 Solar Project. Also provided battery technology advisory, cost estimates, preliminary electrical design, and other owner’s engineering support.


**Additional Project Experience**

Confidential Clients

- 2016 | 20 MW | Central United States | Developed a conceptual layout and energy estimates for a solar PV project being developed adjacent to coal-fired power plant. Evaluated fixed-tilt and single-axis tracking configurations as well as thin-film and crystalline PV module options.

- 2015 | Central United States | Performed a site screening and evaluation study. Studied approximately 50 sites in six states. In addition to the solar resource, evaluated environmental restrictions, land availability, civil engineering considerations, and other site selection matters.

International Finance Corporation

2014 | 70 MW | Philippines | Performed an independent solar resource and energy production assessment of three solar PV projects to support project financing.

Macquarie Capital

2013 | 30 MW | Georgia | Performed an independent solar resource and energy production assessment of a solar PV project to support project financing.

U.S. International Development Finance Corporation (formerly Overseas Private Investment Corporation)

2013–2014 | 5 MW | Tanzania | Performed an independent solar resource and energy production assessment of a solar PV project to support project financing.
CSP Site Evaluation, Solar Resource, & Energy Production Assessments

Selected Recent Project Experience

ACWA Power/Project Lenders

2018–2019 | 700 MW | United Arab Emirates | Acted as lender’s technical advisor for the DEWA CSP project. Project consists of a 100-MW central tower unit with molten salt storage and three 200-MW parabolic trough units with molten salt storage. Services included independent technical due diligence and presentations on technology in support of project financing.

Arizona Solar One, LLC

2020 | 280 MW | Arizona | Solana Generating Station | Performed a latent defect assessment and an analysis of the cause of a molten salt leak failure. Opined on the existence of a latent defect, whether originating from the engineering design or from the manufacture of the tanks. Also opined on whether any other defects (latent or not) existed in addition to the one that caused the crack.

Cerro Dominador

2018–2021 | 110 MW | Chile | Atacama 1 | Monitored construction following a restart of construction efforts on behalf of senior debt lenders. Scope included site visits to the project site and quarterly reporting to project stakeholders. Reviewed budget metrics and drawdown requests as well as construction, procurement, permitting, interconnection, and PV project coordination. Additionally, witnessed commissioning and reviewed commissioning documentation in support of provisional acceptance.

Electric Power Research Institute

2013–2022 | Supported over 25 system planning studies related to the cost and performance aspects of various generating technologies, including solar PV, concentrated solar, onshore and offshore wind, gas turbine, reciprocating engine, and nuclear technologies. Developed cost and performance inputs such as capital costs, operating costs, performance characteristics, generation forecasts, and emissions data. Work was utilized as input for EPRI’s TAGWEB database and their solar PV and wind technology guides, among other purposes.

Additional Project Experience

Abengoa

2015 | 110 MW/10-h Storage | Chile | Atacama Molten Salt Tower Project | Performed an independent technical assessment of the solar resource and performance model (energy yield) for the project lenders in support of financial close.
DEWA Mohammed bin Rashid Al Maktoum

100 MW | Solar Park Project | Phase IV | Performed an independent review of the project’s solar resource assessment and developed a solar performance and production model submitted with the client’s bid. Project consists of two CSP units rated at 100 MW; one unit uses molten salt power tower technology and the other a proven CSP technology.

SolarReserve

- 100 MW/10-h Storage | Nevada | Crescent Dunes Molten Salt Tower Project | Performed an independent technical assessment of the solar resource and performance model (energy yield) for the project lenders in support of financial close.

- 100 MW/10-h Storage | California | Rice Molten Salt Tower Project | Performed an independent technical assessment of the solar resource and performance model (energy yield) for the project lenders in support of financial close.

- 110 MW/10-h Storage | Chile | Copiapó Molten Salt Tower Project | Performed an independent technical assessment of the solar resource and performance model (energy yield) as well as a third-party independent certification for bid submission.

- 100 MW/10-h Storage | South Africa | Redstone Molten Salt Tower Project | Performed an independent technical assessment of the solar resource and performance model (energy yield) for the project lenders in support of financial close.
Conceptual and Detailed Design

Selected Recent Project Experience

Confidential Client

2018 | 8 MW | Caribbean | Developed a conceptual layout, a design, and energy estimates for a solar PV project being developed on an island in the Caribbean. Evaluated fixed-tilt and single-axis tracking configurations as well as thin-film and crystalline PV module options.

NextEra Energy Resources/Florida Power & Light

Florida, United States | Provided engineering and design services for new greenfield solar collection substations:

- 2020–2021 | 75 MW | Delmonte North Solar Farm | 230/34.5-kV solar collection substation
- 2019–2020
  - 75 MW | Harmony Solar Farm | 230/34.5-kV solar collection substation
  - 75 MW | Taylor Creek Solar Farm | 230/34.5-kV solar collection substation
- 2018–2020
  - 75 MW | Ghost Orchard Solar Farm | 500/34.5-kV solar collection substation
  - 75 MW | Leno Solar Farm | 230/34.5-kV solar collection substation
  - 75 MW | Nubbin Solar Farm | 230/34.5-kV solar collection substation
  - 75 MW | Crawford Solar Farm | 230/34.5-kV solar collection substation
  - 75 MW | Plum Solar Farm | 115/34.5-kV solar collection substation
  - 75 MW | Moccasin Solar Farm | 115/34.5-kV solar collection substation
- 2017–2018 | 75 MW | Krome Solar Farm | 138/34.5-kV solar collection substation

Additional Project Experience

Confidential Client

- 2016 | 20 MW | Central United States | Developed a conceptual layout, a design, and energy estimates for a solar PV project being developed in conjunction with a thermal power plant. Evaluated two different sites, fixed-tilt and single-axis tracking configurations, and thin-film and crystalline PV module options.
First Solar

2017–2018 | 150 MW & 100 MW | California | North Rosamond & Willow Springs Projects | Provided engineering and design services for new solar PV projects.

United States Department of Energy/Solar Dynamics

2017 | 250 MW | Southwestern United States | Developed the comprehensive conceptual design for a dispatchable solar plant. The conceptual design for a molten salt power tower included a detailed conceptual design (preliminary drawings and technical specification) as well as details regarding the performance, cost, and schedule.
Owner's Engineer and Technical Advisor

Selected Recent Project Experience

ACWA Power

2020–2022 | 250 MW (total) | Ethiopia | Gaad and Decheto | Provided lender’s technical environmental services. Confirmed whether the projects had been planned and designed in compliance with applicable environmental requirements.

Confidential Clients

- 2022 | Tennessee | Performed owner’s engineering services in the form of a string inverter analysis. Determined key performance differences between the current, central inverter-based architecture with that of two equivalent string inverter configurations.

- 2022 | Texas | Performed an injection study for an existing interconnection substation to support new generation at the facility, a preliminary energy yield assessment, a conceptual site layout, preparation of a generator interconnection request, and additional project development services. In addition to the results of the injection study, provided cost estimates for project development and EPC activities.

- 2022 | Arizona | Provided owner’s engineering support for a solar and BESS project. Provided BESS RFP support by reviewing the technical aspects of the long-term services agreement and updating technical specifications, BESS codes and standards, and the exhibits provided in the RFP.

- 2022 | Arkansas, Indiana, and Iowa | Reviewed the most recent update to the ASCE/SEI 7-2022 code. The assessment included a bulleted list of the main changes to the code and flagging the changes that have the highest potential to impact cost with respect to new solar PV project design and development.

- 2022 | 200 MW | Texas | Supported the renewal of a project interconnection application for submission to ERCOT with new parameters. Provided a full-service interconnection package update. Also previously performed modeling updates for the project.

- 2022 | 177 MW | Tennessee | Provided owner’s engineering services, including a review of a fixed racking system that did not utilize the standard foundations being considered for the project. Support included a review of the geotechnical report to address liquefaction concerns with the site, a general review of the racking system—including bankability and O&M considerations—and a review of the structural calculations to ensure consideration of seismic loading and settlement.
2019–2022 | California | Provided expert witness support regarding the EPC contract price for a solar PV electric generation project. Provided expert witness report, rebuttal report, and expert witness testimony. Provided an opinion on whether the EPC contract price for the project was a fair market value relative to the commercial operation date.

2021–2022 | Texas | Served as a litigation consulting expert in a dispute involving curtailment of a solar PV project. Advised on contractual obligations related to Good Industry Practices for the purpose of determining responsibilities for alleviation of project curtailment.

2021–2022 | Texas | Developed a redesign of the project's stormwater detention pond based on the as-built topography of the solar field portion of the project. Redesign included drainage calculations, updated drawings, and redesign of the pond outlet structure and downstream mitigation.

2021–2022 | 200 MW | Texas | Provided civil engineering design services. Scope included design submittal package milestones at 30%, 60%, 90%, and upon being issued for construction.

2021–2022 | 200 MW | New York | Prepared a large generator interconnection application for submission to NYISO. Preparation included the single-line diagram, PSSE models, and required forms.

2021 | Texas | Provided owner's engineering support for a solar and BESS project. Project scope included EPC submittal reviews for the PV and BESS aspects of the project, including civil, structural, and electrical design reviews.

2021 | California | Provided detailed flowgate (generator deliverability detail) reports for identified GLW-VEA constraints.

2021 | 54 MW | Illinois | Performed a detailed WTG foundation design analysis of existing P&H tensionless piers for the possibility of upgrading the turbines. Provided a design calculation summarizing the key aspects of the analysis as well as an updated set of signed and sealed design drawings.

2021 | Iowa | Performed a broad screening study for available injection and withdrawal capacity in the MISO Iowa territory. Investigated and ranked the top 100 POIs in the voltage range of 115–345 kV for potential solar facilities proposed to enter the MISO interconnection queue.

2021 | Georgia | Provided owner’s engineering services to support project development. Services included a one-day site visit to the proposed project site with interviews to discuss the facilities study. Also provided a brief summary report of the meeting and geo-referenced photos.

2021 | Louisiana | Provided technical and coordination support for the filing of interconnection applications to MISO. Support covered the preparation of application documents, single-line diagrams, and a supplemental information package as required by MISO (e.g. PSS/E models). Maintained direct coordination with the MISO interconnection team.

2020–2021 | 1.5 MW | Michigan | Provided engineering support and technical advisory services for the development of a distribution-level solar project. Support included a conceptual design review as well as optimization and interconnection application support. Also filled out the interconnection application on behalf of the client.
• 2020–2021 | 25 MW | Michigan | Provided engineering support and technical advisory services for the development of multiple solar projects. Support included conceptual design reviews as well as optimization and interconnection application support. Separate interconnection applications were filed for different project portions, including a 20-MW PV array and a 5-MW PV array.

• 2019–2021 | 420 MW + 40 MW/40-MWh Storage | Texas | Provided technical support for the development, construction, and commissioning. Support included conceptual design, energy production estimates using PVsyst, RFP development (technical specifications), administration, bid reviews, EPC selection, and EPC submittal reviews.

• 2020 | 330 MW | Texas | Provided EPC submittal design reviews for a solar PV project.

• 2020 | 300 MW | Indiana | Provided owner’s engineering services for a PV project. Services included upfront contracting support, design reviews, and construction monitoring.

• 2020 | Michigan | Provided technical advisory support for layout optimization and support throughout the interconnection process. Scope included an optimized yield for the site based on inverter location, row spacing, module tilt, and road widths throughout the site. Also provided single-line diagrams and CAD layout drawings for the interconnection application.

• 2019 | Michigan | Provided technical and coordination support for the filing of interconnection applications to MISO. Support covered the preparation of application documents, single-line diagrams, and a supplemental information package as required by MISO (e.g. PSS/E models). Maintained direct coordination with the MISO interconnection team.

• 2019 | 400 MW | Texas | Provided owner’s engineering services to support conceptual layout design optimization, tracker technology selection, and EPC bid solicitation for a project.

• 2018–2019 | 100+ MW | Midwestern United States | Provided owner’s engineering support for a solar PV project. Managed the interconnection application process.

• 2018 | Northern Africa | Provided technical advisory services for new solar (200 MW) and wind projects. The scope focused on implementation support for a solar PV IPP tender. Key activities included further implementation support covering tender clarification, bid evaluation, selection of and negotiation with shortlisted bidders, award of the project to the preferred bidder, and finalization and execution of the project documentation with the preferred bidder. The technical review included an evaluation of plant design, yield assessment, main equipment suitability, equipment warranties, experience of EPC and O&M contractors, and overall schedule.

• 2018 | United States | Prepared a solar PV project technical specification for a utility-scale project.

• 2018 | California | Prepared MISO interconnection applications for four separate solar and battery storage projects between 100 MW and 200 MW.

• 2018 | 100 MW | Mexico | Served as owner’s engineer for a solar PV project. Deployed personnel to the site during the construction and commissioning phases.

• 2018 | 40 MW | Michigan | Performed site identification and site evaluation studies for 20 solar projects; each project was 2 MW in capacity. Used geographic information system tools to perform the study. Managed the interconnection application process.
First Mile Development, LLC

2022 | Performed consulting services related to the transmission-based siting of solar PV projects in the MISO region. Provided high-level guidance of the interconnection viability based on the technical parameters of the project, interconnection facilities, and any known system constraints. Provided recommendations for further analysis to gain a fuller understanding of interconnection viability.

Leeward Renewable Energy, LLC

2022 | Arizona | Elisabeth Solar Project | Determined the potential shading impact of a proposed transmission line on a PV array; the assessment showed the extent of PV array shading at different times of the day/year. Provided a qualitative opinion on the generation impact and optimal setback distance of the transmission line from the PV array.

Mitsui Mitre Calera Solar S.A.P.

2018–2019 | Mitsui Calera Project | Served as the owner’s engineer for a solar PV project.

Ørsted Onshore North America

- 2020–2021 | 227 MW | Alabama | Muscle Shoals | Provided owner’s engineering services to support project acquisition. Reviews were focused on site studies, EPC contract technical exhibits, PV design deliverables, and high-voltage designs. Also provided miscellaneous support as requested.
- 2020–2021 | Texas | Assessed the operational and financial implications of extending a PV project’s life from 35 to 40 years. Identified a strategy to extend the lifetime to 40 years. Assessment included identifying early-stage design and procurement decisions related to project life, O&M considerations, and commercial considerations. Created an O&M cost forecast.

PNE USA, Inc.

- 2022 | 199 MW + 100-MW BESS | Idaho | Market Lake | Provided an update to the previously developed conceptual design (site layout and single-line diagram). Provided a preliminary conceptual production model of the solar facility. Provided a high-level estimate of the capital expenses associated with the solar PV and BESS facilities.
- 2022 | Provided energy models and capital expense estimates for a solar and battery storage project. Used the conceptual site layout as the basis of the energy yield assessment for the project. Provided a high-level estimated range of the capital expenses and operating expenses associated with the project. The sites were as follows:
  - 50 MW + 10-MW BESS | Illinois | Kishwaukee
  - 50 MW + 10-MW BESS | Pennsylvania | Mountain City
  - 199 MW + 100-MW BESS | Utah | Red Butte
Potentia Renewables, Inc.

2021–2022 | Hawaii | Kamaole Solar Project | Provided owner’s engineering services for a solar PV and energy storage project. Prepared BESS specification and provided recommendations to the client on potential qualifying vendors. Prepared a technical specification for the procurement of the main power transformer. Provided review and recommendations on a list of solar panel tracker vendors. Provided preliminary PV and battery sizing, project site layout and optimization, and an energy yield assessment.

Rancho Seco Solar II

2020 | 160 MW | California | Performed high-level desktop review of generator step-up transformer and the substation design, collection system design, and solar PV inverter design to evaluate potential risk for harmonic issues. Results indicated that harmonic risk was high; subsequently, conducted a predictive harmonics study.

RRC Power & Energy, L.L.C.

- 2022 | 200 MW | Texas | Big Star Solar Project | Designed a drainage system around the transmission line pad and a drainage and stormwater management system to bypass the BESS yard. Scope included design of a concrete junction box in support of the stormwater management system.

- 2022 | 200 MW | Texas | Big Star Solar Project | Provided updated design calculations for drainage and pond design. Provided recommendations for drainage channel widths and erosion protection requirements to limit the flow depth and velocity of the pond discharge. Calculations required revision since the contractor did not install the original design in accordance with the drawings. Calculations were developed to limit rework onsite.

- 2021–2022 | 0.99 MW | Texas | Kerville Solar Project | Developed a redesign of the project's stormwater detention pond based on the as-built topography of the solar field portion of the project as part of a separate scope. Completed updates to the calculations and design in support of use of a smaller pond.

- 2021–2022 | 200 MW | Texas | Big Star Solar Project | Designed a drainage system around the transmission line pad and a drainage and stormwater management system to bypass the BESS yard. Adjusted the scope based on reconfigurations of the T-line design. Also designed a sheet pile design with the intent to provide shoring protection and limit the extent of excavation for the drain system designed. Reviewed the civil design, final civil drawings, and hydrology report.

Swift Current Energy

2019 | Illinois & Arkansas | Prepared PJM and MISO interconnection applications for three separate solar projects and two wind projects between 200 MW and 600 MW.
U.S. International Development Finance Corporation (formerly Overseas Private Investment Corporation)

2016–2022 | 100 MW | El Salvador | Bosfor Solar PV Project | Served as lenders’ technical advisor for the financing of a collection of solar PV projects in El Salvador. Engagement extended through initial due diligence, construction monitoring, and operations monitoring. Performed technical design reviews, budget reviews, and conformance with international project finance standards, including Equator Principles.

Additional Project Experience

Agrífas Fertilizer

2009 | Texas | Assessed various renewable energy generation options that could be used at a site in southeastern Texas. Investigated solar thermal and solar PV technologies. Evaluated performance, cost, and incentives for the various technologies.

Alstom

2015 | 100 MW | Israel | Ashalim Project | Developed the technical specification and review of bids for the tower structure for a molten salt power tower project.

Arizona Electric Power Cooperative

2007 | Apache Station | Created a functional specification for a gas turbine solar inlet chiller system.

BP America, Inc.


California Solar Ranch, LLC

2016 |Reviewed the technical performance and conducted a cost study for a hybrid solar plant.

Confidential Clients

- 2016 | United States | Conducted a decommissioning study, including cost estimates and environmental review, for the dismantlement and scrap of various sites, including wind projects and solar PV arrays.
- 2013 | 30 MW | South Africa | Performed a pre-feasibility study for a solar PV facility. Scope included a solar resource evaluation, conceptual design, generation projection, interconnection review, and overall risk analysis.
- 2011 | India | Developed the conceptual design for a parabolic trough plant. Conceptual design included a review of technology, a solar resource assessment and projection, a conceptual design—including the solar field size, HTF system, and power block—and conceptual design drawings—
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including the solar field layout, heat balance, electrical one-line diagram, control block diagram, and water balance.

- 2011 | Developed the detailed design for a solar field and HTF system. Solar field design included foundations. HTF system design included a complete design package for purchase, installation, and commissioning.

- 2010–2011 | Southwestern United States | Conducted project and technology due diligence reviews of solar thermal projects. Reviews included both technology and general project risk.

- 2009–2011 | Conducted technical due diligence of eSolar direct steam power tower technology.


- 2006, 2009, & 2010 | Conducted a feasibility review of the Brightsource direct steam power tower technology proposed for large-scale solar plant.

- 2007–2009 | Reviewed a solar technology supplier (SkyFuels) for an investment group and developer.

- 2008 | Performed technical due diligence of three solar distributed power tower technologies being developed in the United States. Reviewed the design concept and implementation strategy for each.

**CPS Energy**

2011 | 30 MW | Texas | Performed a technical review and construction monitoring of three 10-MW PV projects.

**Duke Energy Generation Services**

2007 | Evaluated solar trough and tower technologies, including current costs and potential cost reductions.

**Electric Power Research Institute**


- 2017 | Provided client with a PV solar project decommissioning guide.

- 2009 & 2010 | Provided client with plant descriptions, estimated costs, and associated technical information on solar thermal and PV electric power generation technologies. Information included: (i) the current status and potential projections for development and/or commercialization activities over the next 5–15 years; and (ii) issues and activities associated with renewable power generation technologies as they relate to planning, engineering, and project development.
Entegra Power Group

2009 | Gila River Project | Analyzed the use of both parabolic trough and PV technologies. Parabolic trough CSP configuration was based on integration with the existing combined-cycle configuration of the project. PV configuration was based on non-tracking, thin-film PV panels. Analysis included capital costs, O&M costs, water usage, land requirements, staffing, achievable performance, and technology maturity.

Florida Power and Light

- 2005 | SEGS III & VII | Performed a due diligence review for project refinancing, including a condition assessment, reviews of O&M practices and budgets, and assessments of plant performance, financial projections, and the status of permitting and licensing compliance.
- 1998 | SEGS VIII & IX | Performed a due diligence review for project refinancing, including a condition assessment, reviews of O&M practices and budgets, and assessments of plant performance, financial projections, and the status of permitting and licensing compliance.

Goldman Sachs

2006 | 600 MW | Southwestern United States | Provided engineering services for the development of a large-scale parabolic trough plant. Services included conceptual design and a conceptual cost estimate.

HIRCO

2010 | India | Provided engineering services for the feasibility of parabolic trough technology at an existing site as well as an analysis of expected project costs while considering local factors.

Intermountain Power Agency

2009 & 2010 | Utah | Provided engineering services regarding the feasibility of various solar technologies (tower, trough, and PV) at an existing site.

InterGen

2008 | Conducted a feasibility study of a solar retrofit for a 501F 1x1 combined-cycle unit. Addressed parabolic trough, power tower, and compact linear Fresnel receiver technologies. Identified relevant advantages and disadvantages of each. Evaluated achievable team conditions, technology maturity, comparative capital and O&M costs, and equipment availability.

LUZ Solar Partners

- 1997 | Since the original operation of the units, provided engineering support to the operating companies to improve efficiency and reliability. Designed the piping system for added condensate storage tanks, designed bypasses for the HTF heaters, and provided a study of variable-frequency drives, a structural design review, and assistance with turbine blade repairs.
- 1988 | 160 MW total | California | SEGS VIII & IX | Participated in the original design of two 80-MW parabolic trough units. Units have gas-fired HTF heaters, a hybrid design that was considered the
lowest-cost and latest technology. Performed the design of the power block, BOP, and interface with the solar field. Efforts included the design of SEGS X, for which construction was started but not completed.

**Mesa del Sol**

2008 | 100 MW | Southwestern United States | Calculated a high-level capital cost estimate and O&M costs for a solar parabolic trough plant.

**National Rural Electric Cooperative Association**


**Sempra**

- 2009 | 50 MW | Southwestern United States | Provided engineering services for the feasibility and selection of large-scale battery systems for a thin-film PV plant. The study included a review of available battery technology, the maturity of the technology, capital and O&M costs, and methodology to size the battery and determine the optimum battery type based on technology and cost.
- 2007 & 2009 | Southwestern United States | Provided engineering services for the development of a large-scale parabolic trough plant. Services included conceptual design of the entire plant (solar and thermal), a conceptual cost estimate, EPC specifications, technical input for permitting (emissions and transmission), schedules, and additional support as required.

**SkyFuels**

2010 & 2011 | SkyTrough | Conducted an independent technical review of a parabolic solar collector. Services consisted of a review of the design, a comparative product cost assessment, and a performance assessment. Evaluated the prototype testing and opined on the results.

**SolarReserve**

2014 | 110 MW/10-h Storage | Chile | Copiapó Project | Performed an independent technical assessment of the solar resource and performance model (energy yield) and provided a third-party independent certification for submittal of the bid by SolarReserve for the molten salt tower project.

**Southern California Edison**

2008 | Mohave Power Plant | Studied potential project uses. Services included developing a conceptual design and cost estimates for a parabolic trough solar plant, power tower, and integrated solar combined-cycle plant.
State Government of India

1996 | 405 MW | India | Advised state governments on three proposed solar chimney projects in India: a 5-MW project in Gujarat and two 200-MW projects in Rajasthan and Gujarat. Effort included a technical, economic, and design feasibility report as well as coordination with the developers.

Total/Abengoa

2008 | United Arab Emirates | Provided bid support for a solar thermal power plant. Services included independent technical verification that the EPC contract proposal for the bid complied with the requirements identified in the RFP, including the PPA. Also provided technical assistance in preparing a competitive bid and identifying technical risks.

Toyota Tsusho Corporation

2011 | Conducted a comprehensive technology survey and analysis of commercially available solar thermal and solar PV technology.

U.S. Department of Energy

- 2008 & 2009 | Updated Assessment of Parabolic Trough and Power Tower Solar Technology Cost and Performance Forecasts (May 2003) to include parabolic trough, molten salt power towers, direct steam power towers, and dish technology. Issued the draft report for industry review in April 2009.
- 2003 | Assessed the potential for developing CSP technology as an electric generating technology over the subsequent 10–20 years. Analyzed industry projections for technology improvement, the progress of research and development, plant scale-up and economies of scale, economies of learning from increased deployment, and cost-reduction potential. Considered possible improvements in efficiency, tax credits, O&M cost, and total cost of produced electricity. Developed an extensive network of contacts in the solar thermal industry, including persons in government, research organizations, and equipment manufacturers. Analyses considered a variety of sensitivity studies, including the impacts of owners’ cost of capital (e.g., investor-owned utilities versus other types of utilities with lower financing costs).

Vistra Energy

2017–2018 | 180 MW | Texas | Upton 2 Solar Project | Provided owner’s engineering services to support adding battery energy storage. Services included battery technology consultation, cost estimates, preliminary electrical design, and other owner’s engineering support.

The World Bank

1999 | Mexico | Comisión Federal De Electricidad (CFE) received funding from the Global Environmental Facility (GEF) of the World Bank for the solar portion of an integrated solar combined-cycle system thermal power generation project. Assessed plant feasibility based on a change project contracting and technical changes. Scope included: (i) summarization of current CSP technology development and experience; (ii) appraisal of the technical soundness of the CFE-proposed design and its status in terms of technological
progress; (iii) a review of technological arrangement alternatives; (iv) an assessment of incremental costs and the economic feasibility of the CFE-proposed design; and (v) an evaluation of technological performance risk, cash-flow risk, project financial return risk, developer financial return risk, and policy risk for the project. Work included a review of the solar field (insolation, field configuration, and geotechnical reviews) and the combined-cycle plant. Combined-cycle analysis included an evaluation of the absorption chillers, powered by solar generated steam, that were used for cooling the combustion turbine inlet air to maintain a constant inlet air temperature.
Sargent & Lundy's involvement in the alternative fuels industry includes feasibility studies, fuel supply assessments, evaluations of technology options, siting evaluations, the identification of “target” emission rates for air permitting activities, layouts, and cost estimations. Our project development work has included conceptual design with the ability of burning biomass; this work has involved investigating optional equipment layouts based on information gathered from steam generator suppliers, material handling vendors, and air quality control vendors to assure our clients that new or existing coal-fired units could also be able to fire biomass in enough quantities to impact CO₂ emissions. In addition, we have investigated WTE projects and alternative fuel co-firing in both existing and new units.
Alternative Fuels Projects

Selected Recent Projects

B&W Vølund

- 2019 | Indonesia | Sunter WTE Plant | Industrial Waste | Provided detailed structural engineering and design for the steel structure to support the boiler, economizer, combustion grate, air ducts, piping, and all related equipment within the boiler island. The scope included connection design for a high-seismic location.

- 2017 | Provided technical advisory services for various WTE projects.

Babcock & Wilcox Company

- 2017 | Black Bin Waste and Biomass | Provided engineering oversite and technical advisory services:
  - Detailed cost analysis
  - Advisory services on potential construction partners
  - Engineering site support and in-office coordination assistance of client’s design
  - Plant design risk mitigation/optimization
  - Detailed electrical design
  - Mechanical and structural design oversight
  - Document control services for ongoing projects
  - Technical support for government interfaces
  - Schedule analysis, development, and support (at site and in office)
  - Site construction scheduling

Confidential Clients

- 2017–2021 | 70 MW | Philippines | Conducted an independent engineering due diligence review of three biomass power projects being developed on the island of Negros. All three plants were designed to generate power using sugar cane trash sourced from local farms.

- 2020 | Saudi Arabia | Provided off-grid development support for solar PV, solar CSP, wind, battery storage, and biodiesel technologies. Supported development of a compliant and optimized proposal for a long-term BOOT proposal for the utilities’ systems for said off-grid development. Ran PLEXOS to determine optimal generation mix scenarios containing primarily renewable resources and BESSs. Generation source options included solar PV, solar CSP, wind, and the restricted use of reciprocating engines running biodiesel. Performed an analysis to assess the load-shifting and
thermal storage opportunities related to operation of a district cooling plant and seawater desalination plant. Also performed network analysis studies on the planned high-voltage network to ensure electrical functionality of the mini-grid system, as proposed.

- 2018–2019 | 36 MW | Hawaii | Served as independent engineer for the potential investment in a wood-fired biomass project under development. Services included technical and financial due diligence in support of a tax-equity investment evaluation, including an in-depth assessment of the boiler design.

Covanta Energy LLC

- 2017 | Performed condition assessments focused on fire protection of older WTE power plants. The project consisted of two separate facilities located at one site and sharing a common wall on refuse-receiving areas with boilers at each feeding the respective turbine generators. Performed walkdowns of the facilities, interviewed O&M staff, and observed operations. Also provided technical recommendations to improve fire safety, considering housekeeping, facility design, latest industry practices, and current codes and standards.

Cube Mas Energy

2017–2019 | Georgia (United States) | Performed an independent engineering review of the methodology used in estimating operating expenses for two LFG projects.

Korea Electric Power Company

2018 | Georgia (United States) | Provided technical advisory services for two biomass projects.

NOVI Energy

2010–2014 | 50 MW | Virginia | Served as owner’s engineer and provided technical support for project startup activities through EPC award for the brownfield development of a nominal boiler facility. Scope included development of a feasibility study to assess technology, fuel, interconnection and environmental and site characteristics. Retained to support permit applications, the PJM interconnection application, development of EPC specifications, EPC bid evaluations, and guidance for economic incentives. Performed a detailed design in civil/structural areas outside the power block and general owner’s engineering support during project implementation. Supported the owner’s application for the Department of Treasury’s 1603 ARRA Grant funding, providing detailed cost estimate breakdowns and general guidance.

Additional Projects

Antilles Energy Cooperative

2009 | Lower Somerset Renewable Energy Facility | Provided owner’s engineering for project startup activities for the conversion of an existing generating facility from fuel oil to a biomass feedstock of poultry litter and agricultural feed. Feedstock processing included gasification for combustion, liquefaction to liquid biofuel products, and associated process stream cleanup. Assisted in developing the project’s commercial
structure, defining the plant’s division of responsibilities and preliminary permit scoping while generating an integrated project schedule.

**Associated Electric Cooperative Incorporated**

2010 | Missouri | Evaluated biomass co-firing options at five existing coal-fired units—ranging in size from 175 MW to 715 MW—and using pulverized coal and cyclone technologies. Scope included a fuel analysis, co-firing technology options for both boiler types, performance calculations, material handling design considerations, emissions and permitting impacts, economic analyses, and an implementation schedule analysis.

**Biomass Products, LLC**

2010–2011 | 25 MW | Illinois | Rock Falls Biomass Power Plant | Provided owner’s engineering support for obtaining transmission services for the proposed. Scope included consultation regarding a proposal to the regional transmission authority and an analysis of the historical locational marginal pricing to assist in determining bid pricing. Analysis included the identification and assessment of transmission service alternatives for delivery into regional transmission territories.

**Buena Vista Biomass Project**

2010–2012 | 18 MW | California | Buena Vista Biomass Project | Provided lender’s engineering support for financing the conversion of the brownfield project. Scope included an initial evaluation of the technical and commercial basis for the project and subsequent periodic reviews and approvals of contractor invoices and change orders. Implemented site visits and regular project team communications to maintain an adequate level of insight into project progress.

**City of Ames, Iowa**

2015–2016 | Iowa | City of Ames Steam Electric Plant Units 1 & 2 | Boiler conversion from coal and RDF to gas, coal, and RDF combustion. Project included the elimination of the main control board to the distributed control system and relocation of BOP programmable logic controller-controlled systems to the plant distributed control system, including the RDF system.

**City of Escanaba & Wisconsin Public Power, Inc.**

2006–2008 | Michigan | Siting and project feasibility study for new solid fuel generating unit of up to 300 MW jointly owned and operated by both clients. Considered fuel was a blend of coal and petroleum coke, with up to 8% heat input provided by wood chips.

**City of New Ulm**

2007–2009 | 10 MW | Minnesota | Evaluated the conversion of an existing 10-MW stoker that had been firing on natural gas to one that fires on coal and biomass. Scope included material handling options, boiler performance, and air emission estimates.
CLECo

2007 | Rodemacher Unit 3 | Conducted a feasibility study of 2x330-MW CFB boilers under construction to burn biomass. Evaluation included environmental considerations, performance assessments, and economic analyses based on a 2010 service date. Also reviewed the quantity and type of biomass near the site.

Cleveland-Cliffs Northshore Mining

2008–2009 | Silver Bay | Evaluated co-firing up to 25% biomass (heat input) from a product line, called Renewafuel, owned by the parent company. Evaluated methods of burning the fuel as defined by the Renewafuel specifications in Unit 2 at the Silver Bay Unit 2 boiler. (Renewafuel proprietary fuels are a blend of renewable feedstock and can be sized for boiler- or furnace specific applications. Densified and custom-sized pellets allow immediate use in most existing solid fuel systems, with minimal capital improvements. The densified biofuel is consistent in size, heat value, and moisture content, so it is easier to store and use than raw biofuels.) Reviewed the installation of new burners dedicated to the biomass fuel alone, and also reviewed several standalone combustion options (e.g., Dutch ovens, gasifiers) that minimized the impact to the existing mills and burners. All options reviewed included evaluation of a new material handling system.

Also evaluated unit performance impacts and estimated changes to SO₂, NOₓ, PM, Hg, and CO₂ emissions. Estimated capital expenditures, O&M costs, and completed an overall plant economic evaluation, including projected cash flow.

Confidential Clients

- 2011 | Midwestern United States | Performed a Phase 1 engineering study and report for utilizing waste fuel to be delivered to existing sites for gasifying the biomass material and using low-Btu fuel in existing boilers to offset the use of coal firing.

- 2010–2011 | Western United States | Conducted a biomass fuel supply and co-firing (up to 10% by heat input) study. Initially, conducted a fuel supply investigation to determine the types of fuel readily available, the quantities and sustainability of each, and the suitable delivery concepts to the station. Performed a technical assessment to determine the method(s) of co-firing the fuels that may be readily found near the station. Presented material handling concepts based on viable fuel alternatives identified in the fuel assessment evaluation.

- 2009–2010 | Midwestern United States | In conjunction with a re-powering study, evaluated the conversion of two existing PC-fired boilers to burn biomass with a percentage of refuse-engineered fuel. Deliverables included site arrangement drawings, a cost estimate, layout and flow diagrams for a completely new biomass material handling system, a fuel alternatives assessment, a conversion technology assessment (co-firing or switching to 100% biomass), a performance optimization, a project schedule, and emission estimates for permitting input.

- 2009 | Midwestern United States | Supporting the biomass conversion of two existing PC-fired boilers to burn biomass with a percentage of refuse-engineered fuel. Deliverables include site arrangement drawings, a cost estimate, layout and flow diagrams for a completely new biomass
material handling system, a fuel alternatives assessment, a conversion technology assessment (co-firing or switching to 100% biomass), a performance optimization, a project schedule, and an emission estimates for permitting input.

- **2009–2010 | Pacific West United States |** Conducted a biomass conversion study for a large coal-fired unit, including the evaluation of co-firing from 10–100% biomass. Report provided layouts, estimated costs, estimated emissions, and an evaluation of a new biomass material handling system (wood chips, grasses, pellets, and torrified biomass) and fuel supply for the type and quantity available.

- **2009–2010 | South Atlantic United States |** Conducted a biomass conversion study for two older PC-fired boilers to burn 100% biomass, including material handling layout integration with an existing system. Over 15 material handling options were under consideration, involving various degrees of long-term and short-term storage, rail and truck delivery, and additional truck traffic. Deliverables included the estimated cost, boiler technology selection (stoker vs. bubbling fluidized bed [BFB], or standalone gasifier), and emission and performance projections. Also developed a detailed conversion scope and inputs to the air permit application.

- **2009–2010 | Midwestern United States |** Performed a biomass conversion study for two large coal-fired units, which included evaluating co-firing from 10% biomass. Report included material handling layouts, estimated costs, estimated emissions, and evaluations of the material handling system preparation equipment costs (wood chips, grasses, pellets, and torrified biomass) as well as the fuel supply for the type and quantity available.

- **2009–2010 | Midwestern United States |** Conducted an independent engineering assessment of an operating biomass unit with a single boiler and steam turbine. Assessment included reviews of fuel supply, system performance, environmental compliance, operations, staffing, and PPA and fuel supply agreements. Fuel consisted of 100% biomass from multiple sources, including wood, harvest, and poultry project byproducts.

- **2008–2009 |** Studied material handling issues associated with receiving and unloading wood chips at an existing CFB unit and conveying to the boiler. Target biomass fuel consumption was ~20% on a yearly average basis, maximum of 40%, by the heat input of wood chips.

- **2007 | 200 MW | British Columbia, Canada |** Created a conceptual design of the power block—including material handling layouts for a nominal 200-MW greenfield CFB unit—with the capability of firing up to 40% wood chips. Layouts were prepared for wood truck unloading, storage, reclamation, and preparation to feed an existing CFB boiler. Supported the air permit application on behalf of the client; scope included developing performance values—such as heat rate, emissions, waste quantities, and water consumption—along with estimated bus bar costs.

**Corval-Ryan J.V. LLC**

- **2011 | Indiana | Peru Station |** Performed a RDF conversion feasibility study.

- **2011 | Indiana | Whitewater Station |** Performed a RDF conversion feasibility study.
Credit Suisse First Boston

2007 | 10 MW | Malaysia | Aokam Perdana Timber Complex | Performed a technical evaluation and feasibility study for the sale of a wood waste power plant. Included a review of the process, high-level condition assessment of the equipment, and review of the O&M and production capability.

Dairyland Power Cooperative

2009–2011 | Wisconsin, United States | Evaluation of the availability of various biomass fuels for use at multiple stations in the client’s fleet; also considered combustion alternatives applicable to each unit. Technologies included modifications to support several co-firing options; boiler conversions to stoker/BFB; and external combustion alternatives, such as Dutch ovens and full and partial gasifiers producing syngas. Different material handling options were identified for each of these firing options due to the different sizing requirements of the technologies. The study identified estimated quantities of each biomass type within reasonable distance from each site. Additional scope includes developing a test burn for several biomass fuel types and selecting the candidate unit for testing, as well as identifying fuel suppliers and temporary material handling equipment required for the test burn.

ecoPower Generation LLC

2009–2010 | 50 MW | Provided owner’s engineer technical support for project startup activities for the greenfield development of a fluidized bed boiler facility to burn wood waste from a local Kentucky lumber industry and forestry. Scope included a technology assessment and selection, conceptual design, technical support to the permitting process, site planning—including material handling unloading storage and reclamation operations—and permit support and consultation for economic feasibility.

Entergy

2008 | Little Gypsy | Conducted a feasibility study of CFB boilers (2x330 MW each) to repower an existing steam turbine fired on biomass. Evaluation included environmental considerations, performance assessments, and economic analyses based on a 2010 service date. Also reviewed the quantity and type of biomass near the site.

Indiana Inland Steel Company

1989 | Indiana | Assessed the condition of a powerhouse system and its components. Identified and evaluated alternatives for upgrading the powerhouse. Alternatives included burning process waste, paper, and wood currently being recycled.

International Finance Corporation

2014–2019 | 70 MW | Philippines | Served as independent engineer for a portfolio of three biomass projects being financed by the client. Services included technical due diligence in support of funding and construction monitoring.
Kauai Island Utility Cooperative

2011 | Hawaii | Port Allen Station | Performed a high-level feasibility review regarding the installation of a new boiler to replace an existing oil-fired package-type boiler to combust biomass. Options included reuse of the existing stream turbine generator, replacement of the steam turbine, reuse of the existing generator and auxiliaries, and replacement of the entire steam turbine generator.

MidAmerican Energy

2008 | Evaluated the availability of various biomass fuels for use at several coal-fired stations in the client's fleet. Study involved the assessment of boiler operations, air quality control equipment, material handling, and the impact of onsite space requirements. Also studied the sensitivity of providing up to 10% of biomass fuel to each unit. Estimated emissions with the different types of fuels studied—including SO₂, NOₓ, PM, Hg, and CO₂—and provided an economic analysis of the capital expenditures, O&M expenses, delta fuel costs, and sensitivity on the value of CO₂ credits.

In a separate study, reviewed the technologies available for a 100% biomass-fired steam generator supplying a separate steam supply, including the appropriate material handling system, which is different from that used to prepare the fuel for direct injection into the boiler. Approximate size was 30–35 MW, including stokers, CFB boilers, and small gasification units.

Minnesota Power

- 2001 | Laskin Station | Studied the addition of a new boiler to an existing site and the repowering of existing steam turbines (fuel included 70% Powder River Basin coal and 30% wood chips) and integration of a new material handling system with the existing coal yard.

- 1985–1987 | Hibbard Station | Provided a conceptual design, feasibility study, and detailed design for converting Units 3 and 4 to burn wood and coal on a traveling grate stoker spreader. Scope encompassed engineering, procurement, and onsite engineering liaising during construction to convert oil-fired boilers, originally designed to burn coal, to fire on wood and coal and to provide a steam supply to a paper mill a half-mile away. Early studies established the feasibility of converting two of the units but dictated an ambitious 24-month schedule from authorization to completion. Boilers required extensive modifications to convert to traveling grate spreader stokers for efficiently firing the new fuel and meeting the paper mill's steam requirements.

Mitsui & Co. Ltd

2003 | Thailand | Developed technical and EPC contract information for the client to submit for a 3x100 MW project using coal and biomass with CFB technology. Scope included development of general arrangements, performance calculations, emission evaluations, site environmental parameters, single-line diagrams, costs estimates, scheduling, and functional plant and system descriptions such as water supply and treatment.
NRG

2010–2011 | Developed the conceptual design for a WTE facility using the AlterNRG (Westinghouse Plasma) gasification technology to produce syngas. Prepared design criteria for the plant, developed an emission profile for submittal of permits, prepared general arrangement drawings, and developed a plant cost estimate.

Scimitar Global Markets

2015 & 2017 | Ireland and United States | Carried out the valuation of one biomass project in Ireland and one biomass project in Nevada. Both projects were designed to be 48 MW in capacity and to use a gasification process utilizing a combination of RDF, construction waste, tires, and other biomass fuels.

Southern Illinois Power Cooperative

2000–2003 | 120 MW | Marion Station Units 1–3 | Provided engineering and design services to support the repowering of units that were originally commissioned in 1963. Existing steam turbines remained intact while the existing steam generators were retired and replaced with a single 120-MW circulating fluidized steam generator capable of burning coal refuse, petroleum coke, wood refuse, and tire-derived fuel.

South Mississippi Electric Power Association

2009–2010 | Studied various renewable energy options potentially available to serve load requirements of the client’s member cooperatives. Performed an evaluation of biomass fuel alternatives, including a review of potential renewable energy legislation, an investigation of renewable fuel sources and technologies, and a feasibility study on the use of potentially viable renewable fuels at existing client units, including integration of biomass handling with existing facilities. Technologies included modifications to support several co-firing options, boiler conversions to stoker/BFB, and external combustion alternatives such as Dutch ovens and full and partial gasifiers producing syngas. Also performed an economic evaluation of these renewable project alternatives.

Tondu Corporation

2008 | 60 MW | Filer City | Evaluated NO\textsubscript{X} control options for two 30-MW stoker boilers. Boilers co-fired biomass (wood chips).

Upper Peninsula Power Company

2003–2004 | Performed a siting and technology screening study for the use of wood waste. Evaluated the best locations on the transmission system. Identified the generation technology and capacity options to be used as the basis for the site evaluations. Developed conceptual designs and cost estimates. Options centered on steam generating units capable of burning a mix of wood waste and Powder River Basin coal.

Xcel Energy

- 2013 | Evaluated, scored, and ranked 64 proposals submitted to Xcel Energy that sought funding from the Renewable Development Fund. The technologies involved included ground and rooftop
solar PV, utility-scale wind, small wind, biomass and biogas, anaerobic digestion, battery storage, fuel cells, and hydrogen production.

**Landfill Gas (LFG) Projects**

**Selected Recent Projects**

**Confidential Client**

2020 | Estimated capital and O&M costs for representative renewable technologies, including LFG technology. Created a summary table for which technologies applied to applicable zones. Project included the definition of capacity factors for the applicable renewable technology.

**Cube Mas Energy**

2017–2019 | Georgia (United States) | Performed an independent engineering review of the methodology used in estimating operating expenses for two LFG projects.

**Additional Projects**

**Arrow Canyon LFG Project**

2003 | Nevada | Arrow Canyon Combined-Cycle Facility | Investigated the use of LFG and evaluated production options:

- Compression and treatment of LFG for use as a supplemental fuel in the Siemens-Westinghouse combustion turbines
- Compression and treatment of LFG for use in the combined-cycle burners
- An independent steam boiler/steam turbine facility for electrical generation
- Steam boilers fueled by LFG integrated with the combined-cycle boilers and steam turbines
- Internal combustion engines with and without heat recovery
- Gas turbines with and without heat recovery

Above options were evaluated in terms of plant performance, maintenance, reliability, and cost.

**Dairyland Power LFG Project**

2004 | Evaluated costs associated with potential LFG-to-energy projects to be constructed at two different landfill sites within the client service territory. Scope included: (i) estimates of LFG production and an evaluation of generation technology options, sizing, and performance; (ii) range estimates for capital costs and for O&M costs; and (iii) development of a project pro forma that estimated the annual revenue requirements derived from electric energy sales needed to provide a reasonable rate of return. Pro forma determined annual income based on fixed and variable operating costs, debt service, taxes, insurance, and general administrative costs.
Dallas Clean Energy—McCommas Bluff LFG Facility

2010–2011 | Performed a due diligence review for the purposes of bond financing the proposed project to improve existing wellfield infrastructure and expand processing capacity from 9.8 million ft³/day per day to 14.8 million ft³/day. Analysis included a wellfield and processing facility technology assessment, economic analysis of the project pro forma, validation of LFG recovery projections, a forward renewable gas pricing analysis, and an impact assessment of environmental regulations.

E/S Energy Solutions

2005 | Texas | McCommas Bluff Landfill Gas Facility | Performed due diligence reviews on two alternatives for the McCommas Bluff LFG facility:

- LFG to High-Btu Gas Conversion Project (4.0 million ft³/day) | Previous LFG to high-Btu gas conversion project had been underperforming in capacity factor and availability. Performed a due diligence review of client plans to improve the performance and availability of the facility. Areas of potential improvement or upgrades included reliability of the LFG flow from the landfill, LFG purification, the maintenance program, and selected equipment replacement or upgrading.

- LFG Engine Project (14x1.75-MW reciprocating engines) | Reviewed an alternate plan to install LFG engines to use the McCommas Bluff LFG. Examined proposals for the engine supply, installation work, and engine maintenance. Also reviewed the LFG flow capability from the landfill to support a multiple-engine project over the long term and the proposed LFG purification strategy.

Electric Power Research Institute


Exelon

2003–2008 | Fairless Hills LFG Generating Station Project | Supported turbine inspections/overhauls, boiler studies, and outages to support the dual-unit operation. Also supported BOP improvement services:

- Boiler 4 and 5 Outages: Scope of work specifications, contractor evaluations, and recommendations
- Turbine 2: Scope of work specifications, contractor evaluations, and recommendations
- Boiler 6: Study on the scope and cost to convert to LFG fuel
- Installation of a revenue LFG flow meter interfaced with Waste Management Corp.
- Boiler 4: Replacement of the low-temperature and high-temperature air heaters
- Conceptual design, detailed design, and follow-on work associated with adding a new water treatment plant
- Modified BOP systems
Florida Power & Light

2004 | Rhode Island | Investigated the utilization of LFG at a combined-cycle plant adjacent to the Rhode Island Resource Recovery Corporation landfill—plant consisted of two Westinghouse W501FD combustion turbines, including supplemental burners in the HRSGs. Evaluated the impact of both and untreated LFG in terms of performance issues (e.g., power output, heat rate, and emissions), maintenance issues (e.g., wash frequencies, maintenance cycles, and warranty issues), HRSG performance issues (e.g., duct burners), and the feasibility and economics associated with various LFG cleaning technologies.

Jacksonville Electric Authority

2003 | Evaluated and solved a significant corrosion problem associated with the BOP piping on the reciprocating engine skids firing LFG. Problem was caused by inadequate treatment of the LFG.

Richland & Anderson County LFG Projects

2004–2006 | South Carolina | Served as owner's engineer for the design and installation of two power generation LFG facilities. Client had negotiated the rights to take LFG flared from existing landfills and installed Solar Taurus 60 CT power generation facilities at both sites; Sargent & Lundy reviewed solar equipment and the LFG conditioning skids.

Scope included the review of client-prepared specifications for various LFG system components and associated prefabricated buildings. Reviewed vendor design drawings and direct vendor interface, and provided engineering support for all BOP systems and structures, including assistance with the final site general arrangement, development of an installation package for all the plant equipment, integration of the fuel system components, and reviews of vendor data.
Examples of Sargent & Lundy's active involvement in geothermal energy projects are summarized below.

Selected Recent Project Experience

Confidential Client

2019 | North and South America | Performed a feasibility study for the use of geothermal energy for cooling and heating of commercial and residential buildings.

Additional Project Experience

CMS Generation

2001 | Michigan | Conducted a technology survey and analysis investigation of commercially available renewable energy technologies to be incorporated into the client’s long-term power generation strategic plan. Surveyed technologies included geothermal power.

Confidential Clients

- 2008 | Southwestern United States | Performed environmental reviews for 10 geothermal generating plants.
- 2008 | Studied additional generation adjacent to an existing facility. Generation included noncombustible renewable energy and geothermal options.
- 2007 | Central America | Provided technical support on two geothermal projects. Evaluated failure modes on new and operating turbines, reviewed manufacturer’s root-cause analysis, and formulated independent recommendations on addressing reliability issues.
Electric Research Power Institute

2010 | Updated the geothermal sections of the client’s Technology Assessment Guide.

Enel Green Power North America, Inc.

2013 | Utah | Cove Fort Geothermal Project | Conducted an independent engineering assessment to provide a completion certification report in accordance with application requirements of the United States Treasury American Recovery and Reinvestment Act of 2009 (ARRA) Payments for Specified Energy Property in Lieu of Tax Credits Section 1603. Performed a site visit and reviewed project design documents and agreements.

Inversiones Energeticas S.A. DE C.V.

2007–2010 | 44 MW | El Salvador | Berlin Unit 3 | Provided engineering services to discover the root cause of cracks and evaluate potential solutions. Identified and implemented modifications. Also participated in steam turbine inspections to verify the modification success.

PacifiCorp

2005 | Blundell Geothermal Plant | Provided services associated with well bearing cooling water issues, BR 6 brine pump repairs, derating, and a controls system upgrade.

Southern California Edison

2005 | Mohave Power Plant | Studied alternative/complementary generation resources. Scope included a feasibility analysis of renewable energy, including geothermal energy.
Hydroelectric

Sargent & Lundy has provided extensive engineering and consulting services for hydroelectric power projects worldwide. Recent hydroelectric power consulting and engineering service engagements are summarized below.

**Selected Recent Project Experience**

**Confidential Clients**

- **2021 | 43 MW (14 MW & 29 MW) | Brazil** | Conducted buy-side technical due diligence for two hydroelectric facilities. Reviews included assessments of project hydrological studies as well as the technical design, project condition, and site suitability. Also opined on O&M practices, project commercial agreements, and environmental, health, and social topics while reviewing the portfolio’s financial model.

- **2019 | 725 MW | Peru** | Reviewed hydrology and energy production estimates. Conducted an operational review.

- **2018 | Peru** | Reviewed pertinent documents and performed a walkdown to evaluate the condition of existing reinforced-concrete dam following significant grouting repairs. Formulated recommended improvements to enhance stability, ranging from the removal or stabilizing of upstream earthen slopes to the installation of additional triaxial crack monitors. To restore structural integrity and reduce rate of water flowing through dam, a temporary mechanical seal was installed on the upstream face, and epoxy grout was injected into multiple vertical cracks.

- **2018 | 90 MW | Pakistan** | Acted as lender’s technical, environmental, and social advisor for the potential financing of a new hydroelectric project.
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- 2018 | Armenia | Performed an independent engineering technical due diligence review of a dam safety report in support of financing. Facilities consisted of three hydroelectric plants with four reservoirs and dams situated on and adjacent to a river.

- 2016 | Wisconsin | Performed bid evaluations of six proposals for plant relicensing. Purchase order included work for initial screening, bid questions, and detailed discussions with three short-listed bidders. Provided an overall bid recommendation to the client.

ContourGlobal

2018 | Peru | Santander Hydro Project | Conducted a due diligence review.

International Finance Corporation (Project Owner: Enerjisa Enerji Uretim A.S.)

2011 | 1+ GW | Turkey | Provided lender’s engineering services, including: (i) preconstruction due diligence and an environmental review; (ii) construction and performance test monitoring; (iii) monitoring during startup; and (iv) operations monitoring. Performed over 70 construction monitoring and operations monitoring site visits:

- Adana, Göksu Tributary (Seyhan River)
- Köprü HEPP | 156 MW nominal capacity; 198 GWh annual generation
- Kuşaklı HEPP | 20 MW nominal capacity; 22 GWh annual generation
- Menge HEPP | 89 MW nominal capacity; 88 GWh annual generation
- Yamanlı II HEPP | 82 MW nominal capacity; 120 GWh annual generation
- Adana, Zamanti & Göksu Tributaries (Seyhan River)
- Kavşakbendi HEPP | 191 MW nominal capacity; 496 GWh annual generation
- Artvin (Çoruh River)
- Arkun HEPP | 245 MW nominal capacity; 540 GWh annual generation
- Kahramanmaraş, Göksun Tributary (Ceyhan River)
- Dağdelen HEPP | 8 MW nominal capacity; 23 GWh annual generation
- Hacınoğlu HEPP | 142 MW nominal capacity; 304 GWh annual generation
- Kandil HEPP | 208 MW nominal capacity | 304 GWh annual generation
- Sarıgüzel HEPP | 102 MW nominal capacity; 243 GWh annual generation
- Trabzon, Ögene & Haldizen (Şerah) Rivers
- Çambaşı HEPP | 44 MW nominal capacity; 132 GWh annual generation

Hydro Fraser

2018 | Performed a due diligence review.
Hydro Quebec
2018 | Performed a due diligence review of three small hydro projects.

Kallpa Generacion S.A.
2018 | Cerro del Aguila Project | Conducted a dam fissure evaluation.

Kaukauna Utilities
2018 | Provided advisory services to support client’s potential acquisition of a small operating hydroelectric project.

Master Hydro (Pvt.) Limited
2018 | Arkari Gol Hydroelectric Power Plant | Provided technical, environmental, and social due diligence.

Additional Project Experience

American Electric Power
2015 | Ohio | Performed an independent engineering review of a small hydroelectric project.

Comisión Ejecutiva del Río Lempa (CEL)
2005–2007 | 180 MW | El Salvador | Performed owner’s engineering services for a generator rewind and other changes to increase two generators’ power output by approximately 20% at a hydroelectric plant.

Confidential Clients

• 2016 | Canada | Supplied technical consulting services as part of arbitration support for three hydroelectric projects.

• 2016 | 12 MW | Midwestern United States | Provided technical support and prepared an EPC specification for the upgrade (from 3 MW) of a small hydroelectric project.

ContourGlobal

• 2017 | 404 MW | Armenia | Vorotan Cascade Project | Provided independent technical and environmental due diligence work for three HEPPs across four reservoirs situated on and adjacent to the Vorotan River. Also performed annual monitoring.

• 2016 | Peru and Central America | Performed asset acquisition due diligence of three hydroelectric power plants: two in Peru and one in Central America.

• 2015 | Peru | Chaglla HEPP | Reviewed the project’s hydrology, sedimentation, geology, electromechanical equipment, hydraulic and structural design, annual energy production estimates, project costs, and construction schedule.
Enerjisa Enerji Uretim A.S.

2017 | 64 MW | Turkey | Doğançay HEPP | Served as the lender’s technical advisor. Performed a technical review and an assessment of the environmental and social aspects of the project. Review was designed to verify the project’s compliance with the Equator Principles and the International Finance Corporation’s Performance Standards. Project's results in a power generation of about 168.98 GWh per year.

European Bank for Reconstruction and Development

2013 | Turkey | Alpaslan II Dam and HEPP Project | Served as the lender’s technical advisor and provided due diligence services.

Indiana Michigan Power


Inter-American Development Bank

2006 | Ecuador | 15 MW | Abanico | Provided lender's engineering services, including preconstruction due diligence.

Kaukauna Utilities

2015; 2017 | Wisconsin | Conducted owner's engineer bid reviews to support relicensing of three existing small hydroelectric power plants.

U.S. International Development Finance Corporation (formerly Overseas Private Investment Corporation) & International Finance Corporation

2013–2014; 2016–2017 | Armenia | Performed an independent engineering review as lender’s technical advisor to support financing of acquisition and refurbishment of a hydroelectric project. Performed a technical review of the project, including the project financial statement, hydrological studies, refurbishment plan, interconnection, and key contracts.

Total Fina Elf

2000 | 1400 MW | Argentina | Piedra del Aguila | Provided a due diligence review for potential acquisition.

West LB

2004–2007 | 750 MW | Mexico | El Cajon | Performed lender's engineering services, including: (i) preconstruction due diligence and an environmental review; (ii) construction and performance test monitoring; and (iii) monitoring during startup.
Energy Storage

Sargent & Lundy has been actively involved in numerous energy storage projects that have used a variety of technologies, including batteries, compressed air, and pumped hydropower. Energy storage is a major issue with renewable generation: intermittent fuel availability creates challenges aligning generation with demand. Sargent & Lundy has assessed and designed systems for energy supply, grid stability, and other applications. Below is a summary of our experience.

Selected Recent Project Experience

Able Grid
2019–2020 | 100 MW/100 MWh | Texas | Provided owner’s engineering services for a new BESS.

Associated Electric Cooperative Incorporated
2019–2022 | Missouri | Created a resource planning matrix demonstrating current expected capital costs, operating costs, and performance for different generation technologies. Technologies included combustion turbine, combined-cycle, solar, wind, and battery technologies.

Broad Reach Power

- 2021 | 200 MW/220 MWh | Texas | Dickens Energy Storage Project | Provided design engineering services for a BESS, project substation, and transmission line.
- 2020–2021 | 100 MW/100 MWh | Texas | Bat Cave Energy Storage Project | Provided design engineering services for a BESS, project substation, and transmission line.
- 2020–2021 | 100 MW/100 MWh | Texas | North Fork Energy Storage Project | Provided design engineering services for a BESS, project substation, and transmission line.
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- 2020–2021 | 10 MW/45 MWh | California | Sierra Energy Storage Project | Provided design engineering Services for a BESS, interconnection substation, and distribution line.

Confidential Clients

- 2022–2023 | Utah | Provided owner’s engineering services for a BESS project and developed a site layout.
- 2022 | Texas | Performed BESS due diligence review for a BESS considered for acquisition. Observed construction status and performed a fatal flaw review based on site visit observations.
- 2022 | California | Prepared an independent engineer report summarizing the evaluation of an emissions-free advanced compressed air energy storage facility using large constructed underground caverns and is designed to integrate large amounts of renewable resources.
- 2022 | California | Reviewed a main power transformer specification for a BESS project which was prepared by the engineer of record. Project scope focused on the key technical attributes to determine if the scope of supply was expected to meet the owner’s anticipated needs and industry best practices.
- 2022 | Supported the client in the development of the intake forms for the request for qualifications with BESS vendors. Provided a list of preferred BESS vendors and any available contact information to support their outreach. Assisted the client in responding to the technical inputs required in the BESS vendor intake forms.
- 2022 | Provided development engineering support for BESS projects, including review of commissioning checklists and other technical documentation from multiple battery integrators. Reviewed key battery contract documentation and provided recommendations and document markups.
- 2022 | Texas | Performed a fatal flaw review and evaluated a revenue forecast assessment. Also reviewed the original equipment manufacturers and the major contractor proposals, key specifications, warranties, and term sheets. Finally, reviewed the key inputs to the financial model.
- 2022 | Wisconsin | Investigated and ranked the top 20 POIs per voltage level for potential solar and BESS facilities in MISO territory. Evaluated the POIs using a power-flow analysis. Also studied the Definitive Planning Phase (DPP) 2021 summer peak and shoulder peak scenarios.
- 2022 | 463 MW & 186 MW | California | Supported tax equity investors for two co-located solar PV and storage projects. Work included construction monitoring, technology and design reviews, an independent energy yield assessment, a battery use-case review, and commercial, permitting, and financial model reviews.
- 2021–2022 | California | Performed an independent engineering review in three phases for a BESS. Assessed projected future performance and operating risks by reviewing the selected battery use case, battery technology, balance-of-plant designs, technical requirements and guarantees of commercial agreements, construction progress, and quality control documentation. The three phases included an initial phase, construction phase, and commissioning phase.
• 2021–2022 | Texas | Reviewed the owner’s BESS technical specification package, supported the owner pertaining to site investigations, a review of the EPC bids, selection of EPC bids, and supported EPC contract negotiations with the preferred bidder.

• 2021–2022 | 30 MW | Oregon | Performed due diligence reviews to provide an independent engineer’s certification as required under the PPA. Scope included reviews of the BOP designs, technical requirements, construction progress, quality control documentation, and performance testing documentation.

• 2021–2022 | 500 MW | California | Supported project development via EPC design deliverable reviews and procurement technical support. Scope was divided between PV plant EPC design deliverable reviews, substation/transmission EPC design deliverable reviews, BESS design deliverable reviews, and miscellaneous technical support.

• 2021–2022 | Performed a grid injection capacity study of a solar and BESS project ranging within 100–250 MW. Studied 50 potential points of interconnection and used the TARA software module to evaluate the first contingency incremental transfer capability (FCITC).

• 2021–2022 | 99 MW (each) | Prepared interconnection applications for two projects to MISO. Created the PSSE collector system model and the interconnection application form. Also compiled the inverter datasheets.

• 2021–2022 | 52 MW/208 MWh | California | Reviewed initial fire protection design drawings and identified gaps in the safety system design against applicable design codes. Also commented on permitting expectations based on experience with the particular battery technology with respect to the project jurisdiction’s fire marshal.

• 2019–2022 | Virginia | Provided owner’s engineer support for a BESS project. Evaluated EPC bid documents to verify their compliance with the owner’s request for proposal. After award of the preferred EPC bidder, reviewed and commented on the design documents, technical specifications, filing application, and various other owner expectations.

• 2021 | 200 MW/800 MWh | California | Provided an independent engineering review and evaluation in support of potential acquisition. The project considered an initial phase of BESS installation followed by the potential addition of more battery and solar PV capacity. Reviewed fatal flaws and significant performance and operating risks. Considered the interconnection agreement, offtake agreement, transformer supply agreement, equipment due diligence, capacity and availability guarantees, EPC agreement, budget, and schedule.

• 2021 | United States | Performed miscellaneous, general development support for the client’s upcoming wind, storage, and solar projects on an as-requested basis. Support included interconnection application development, equipment procurement support, the production of single-line diagrams, and civil engineering support. Also assessed PV project operating life and provided O&M guidance.

• 2021 | 415 MW | Georgia & Connecticut | Performed independent engineering due diligence reviews in support of tax equity financing for a portfolio of renewable projects that included solar and solar-plus-storage facilities. Purpose was to assess future performance and operating risk. Scope
included reviews of site suitability, construction, key technology, design, contracts, environmental considerations, permit requirements, and the financial model as well as an independent energy yield assessment.

- **2021 | 15 MW/60 MWh | Florida |** Performed BESS use-case modeling and a financial feasibility review on behalf of a regional southeastern US utility. Conducted sensitivity analyses to optimize key project parameters, including BESS power/capacity, the augmentation strategy, O&M arrangements, and dispatch triggers in consideration of financial, operational, and transmission constraints. Evaluated available revenue streams for the project and recommended a BESS solution that minimized risks and maximized expected value to the project owner.

- **2021 | 60 MW | Texas |** Performed a feasibility review of various BESS options. Work was requested due to significant levels of curtailment. Evaluated the revenue impacts of curtailment with and without a BESS facility.

- **2021 |** Performed a broad screening study for available injection and withdrawal capacity in the MISO southern and central territories. Investigated and ranked the top 100 POIs in the voltage range of 115–500 kV for potential solar, wind, and BESS facilities proposed to enter the MISO interconnection queue.

- **2021 |** Performed miscellaneous general development engineering support for upcoming wind, storage, and solar projects on an as-requested basis. Support included development of soiling and albedo assumptions for multiple PV projects, development of a PV uncertainty model, and PVsyst energy yield assessments. Support also included a BESS technical specification review and development as well as BESS and solar PV technology reviews.

- **2021 | United States |** Supported development of a BESS technical specification for use on upcoming AC-coupled BESS projects. Specification was designed support EPC bid solicitations from EPC contractors. Resulting document covered functional characteristics, equipment and systems, design and engineering, construction considerations, testing requirements, warranty terms, and performance guarantees.

- **2021 | Southeastern United States |** Conducted a BESS use case modeling and a financial feasibility review on behalf of a regional Southeastern US utility. Performed sensitivity analyses to optimize key project parameters, including BESS power/capacity, an augmentation strategy, O&M arrangements, and dispatch triggers in consideration of financial, operational, and transmission constraints. Evaluated available revenue streams for the project and recommended a BESS solution that minimized risks and maximized expected value to the project owner.

- **2021 | 200 MW/800 MWh | California |** Served as independent engineer for a large collocated pilot BESS with a CAISO offtake agreement. Work was performed on behalf of the potential acquirer of
the project. Services included an EPC contract review, a battery supply and guarantees review, a financial model review, and an O&M budgeting review.

- 2021 | 20 MW/80 MWh | Eastern United States | Served as owner’s engineer for a standalone BESS. Drafted technical specifications, administered EPC RFPs, evaluated contractor bids, and performed design submittal reviews of the selected contractor’s submittals. Work included battery supply market evaluations, fire protection design specification reviews, and various technical and commercial reviews in support of project procurement.

- 2021 | 50 MW/200 MWh | Eastern United States | Served as owner’s engineer for a utility-procured BESS and solar PV project at a major international airport. The scope included drafting technical specifications, administering EPC RFPs, evaluating contractor bids, and performing design submittal reviews of the selected contractor’s submittals.

- 2021 | Eastern United States | Served as owner’s engineer for a utility developing a BESS collocated at the onshore substation of a large offshore wind project making export cable landfall along the Atlantic Coast. Scope included feasibility, site selection, and conceptual design evaluations to support the client’s evaluation of the project and procurement strategy.

- 2020–2021 | California | Provided an overview of key potential BESS equipment suppliers, including supplier type, battery chemistries, enclosures, guarantees, warranties, and use cases. Covered quantitative aspects of cost breakdowns, performance characteristics, efficiency, cycling limitations, degradation/augmentation/overbuilding, limitations on charging, density/acreage, and response rate. Additionally, supported the RFP response by assisting with the offer form, technical requirements, and contracting.


- 2020–2021 | 10 MW/40 MWh | Eastern United States | Served as owner’s engineer for a collocated pilot BESS for a large utility developing a fleet of energy storage projects. Scope included drafting technical specifications, administering EPC RFPs, evaluating contractor bids, and performing design submittal reviews of the selected contractor’s submittals. Design reviews included SCADA, metering and electrical design coordination for incorporation of the BESS into the existing solar PV project.

- 2020–2021 | 4 x 65 MW/65 MWh | Texas | Provided owner’s engineering services to support the addition of a BESS to be collocated on the site of a national gas-fired facility.

- 2019–2021 | 40 MW/40 MWh | Texas | As owner’s engineer, provided technical support for the development, construction, and commissioning of a 420-MW PV solar project and BESS. Support included conceptual design, energy production estimates using PVsyst, RFP development (technical specifications), administration, bid reviews, EPC selection, and EPC submittal reviews.

- 2019–2021 | Eastern United States | Developed a procurement program for large East Coast utility to support the addition of 2.1 GW of BESSs and identify value engineering opportunities.
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- 2020 | 115 MW/460 MWh | California | Performed an independent engineering due diligence review of a BESS. Review was performed on behalf of the project’s tax-equity investors. Project is one of the first tax-equity financed battery projects in the United States.

- 2020 | 63 MW | California | Performed an independent engineering review for a 63-MW (4-hour) battery energy storage project on behalf of the PPA offtaker. Review focused on operational protocols and safety designs.

- 2020 | Performed a technical assessment of various energy storage technology options beyond lithium-ion. Evaluated their technology maturity, performance characteristics, current costs, and a range of scenarios around potential future cost decline rates.

- 2019 | 12 MW/5.4 MWh | Midwestern United States | Provided detailed design services for a black-start BESS for two 115-MW combustion turbine generators.

- 2018–2019 | Eastern United States | Performed a technical feasibility study for large East Coast utility to support the addition of battery energy storage to their system. Studied adding battery storage to existing solar projects and thermal power plants.

- 2018–2019 | Western United States | Provided owner’s engineering services and performed a technical feasibility study for sizing of three battery energy storage projects—5 MW/20 MWh, 10 MW/40 MWh, and 20 MW/80 MWh—using existing interconnections to the grid.

FlexGen

- 2021 | 7 MW/25.2 MWh | Indiana | Perry Project | Provided design engineering services for a BESS, project substation, and transmission line.

- 2021 | 7 MW/18 MWh | Indiana | Indian Creek Project | Provided design engineering services for a BESS, project substation, and transmission line.

- 2021 | 1.75 MW/4.8 MWh | Kansas | Solomon Project | Provided design engineering services for a BESS, project substation, and transmission line.

GlidePath

2018 | 18 MW | Pennsylvania | Performed an independent engineering review and evaluation of a battery energy storage project that went into commercial operation in 2015. Review focused on project design, condition, performance, and O&M parameters; specifically, scope included a review of the battery technology, battery array design (string design, rack protection, and battery management systems), and substation (main transformer, bus and breakers, reactive power support, and grounding). Goal was to provide the potential acquirer with an understanding of the project’s overall level of risk relative to other energy projects (in consideration of the projects’ site-specific conditions and factors).

Indeck Energy Services, Inc.

- 2022 | 250 MW | Illinois | McHenry | Provided support for a PJM large generator interconnection application. Prepared a single-line diagram, PSSE model for the project, and site plan for the project.
• 2022 | 105 MW | New York | Provided owner’s engineering services for two independent BESS projects that will be installed where the client’s existing combined-cycle plant will be decommissioned. Provided conceptual design and preliminary engineering, EPC cost estimate, desktop evaluation of decommissioning of the combined-cycle facility, development of a technical specification to be used in the request for proposal package, and supported the EPC selection process. The sites were as follows:
  ▪ 50 MW | Oswego
  ▪ 55 MW | Silver Springs

**Leeward Renewable Energy Development, LLC**

2022 | 200 MW | Colorado | Prepared an interconnection application for a BESS project into Xcel Public Service Company’s “definitive interconnection system impact study process” queue. Verified that the facility met the FERC Order 827 power factor requirement and that the facility would meet voltage and frequency ride-through requirements. Also supported preparation of the system operator’s large generating facility interconnection application form.

**National Grid Renewables, LLC**

2021–2022 | Provided owner’s engineering services in support of planned solar PV and storage projects. Developed technical specifications for power conversion systems for the conversion of DC power from PV arrays to medium-voltage AC collector systems. Also produced a list of recommended PCS vendors based on prior experience and familiarity with industry available products.

**NextEra Energy Resources, LLC**

• 2022 | 230 MW | California | Sunlight Storage | Assessed the design and operating plans for a new BESS that will tie into an existing solar PV array substation. Reviewed written plans for design and operation of the BESS and provided an independent engineering opinion on whether those plans demonstrate that the project is able to operate in a manner consistent with the safety requirements as required under the PPA.

• 2022 | California | Performed independent engineering services to assess the design and operating plans for several new BESSs. Reviewed written plans for design and operation of the BESS and provided an independent engineering opinion on whether those plans demonstrate that the project is able to operate in a manner consistent with the safety requirements as required under the PPA. The sites were as follows:
  ▪ 325 MW/1300 MWh | Desert Peak 1
  ▪ 90 MW/270 MWh | Proxima BESS 2
  ▪ 75 MW/300 MWh | Desert Peak 2
  ▪ 40 MW/160 MWh | Proxima BESS 1B

• 2021–2022 | 1.3 GW | United States | As independent engineer, performed due diligence in support of tax equity financing for a portfolio comprised of solar (1), solar and storage (2), wind greenfield
(2), and wind repower (1) projects across the United States. Assessed projected future performance and operating risks. The solar scope was comprised of site and energy yield assessments as well as reviews of key technologies (including the BESS, when appropriate), system design, environmental and permitting requirements, contractual agreements, and the financial model. The greenfield wind scope was comprised of reviews of the balance-of-plant design, construction, and contractual agreements. Finally, the wind repower scope was comprised of reviews of the foundations, electrical balance of plant, and towers.

- **2020–2021 | 115 MW/460 MWh | California | Blythe III |** Performed BESS independent engineering due diligence review on behalf of tax-equity investors. Project is one of the first tax-equity financed battery projects in the United States.

- **2019 | 10 MW | Oklahoma | Rush Spring Battery Energy Project |** Provided engineering services and equipment procurement support.

**PNE USA, Inc.**

**2022 | 100 MW | Illinois & Pennsylvania | Kishwaukee & Mountain City |** Developed a scope of work for PJM large generator interconnection applications for Kishwaukee (Illinois) and Mountain City (Pennsylvania). Each project’s design was a 50-MWAC solar facility and a 10-MW, 4-hour BESS with a nameplate capacity of 50 MWAC.

**Stella Energy Solutions, LLC**

- **2022 | 3 MW | Indiana |** Prepared an injection study for four points of interconnection considering a 3-MW/4-hr BESS.

- **2022 |** Reviewed the publicly available guidance of MISO regarding the need to register with MISO for the interconnection of a prospective BESS into a distribution system within the MISO territory. Provided a non-binding opinion on this matter based on the guidance provided by MISO.

**Tesla**

- **2019–2020 | 184 MW/736 MWh | California |** Provided detailed design services for a BESS.

- **2019 | 2 MW/4 MWh | Illinois |** Provided detailed design services for a BESS project for ComEd.

**Vistra Energy**

**2018–2020 | 300 MW/1200 MWh | California |** Moss Landing Power Plant | Provided owner’s engineering services to support the development of a new BESS at the project site. Proposed facility would be the largest battery energy storage project in the world.

**Additional Project Experience**

**CAES—Norton**

**2004 |** Provided owner’s engineering services, including development of a CAES conceptual design.
Confidential Clients

- 2016 | Performed due diligence for a private equity client seeking to invest in a battery manufacturing company. Evaluated the technical performance of the battery company’s novel metal-air battery technology and reviewed the company’s financial projections. Also performed a valuation of the company.

- 2016 | Performed a market study and financial evaluation of adding a battery energy system to an existing wind project in the PJM region. Assessed the new PJM capacity performance market to evaluate the battery system economics.

- 2016 | California | Performed a technical feasibility study and conceptual design for integrating battery energy storage into the San Francisco Bay Area Rapid Transit electrical system.

- 2015–2017 | Northeastern United States | Conducted owner’s engineering bid evaluation services for six energy storage projects. Supported technical Q&A and negotiations with bidders. Also supported the offtaker to negotiate the power supply contract.

- 2013 & 2015 | Midwestern United States | Provided cost and performance estimates to a utility for battery storage and pumped storage systems to support resource planning activities.

- 2009–2011 | 60+ MW | Provided engineering services for several energy storage projects totaling over 60 MW. Deliverables included conceptual studies, conceptual designs, detailed designs, construction oversight, and interconnection studies. Projects were intended to provide grid stability, provide power plant ancillary services, and enhance wind facilities’ operation.

Electric Power Research Institute

1998 | Studied and prepared a technical report (*Compressed Air Energy Storage with Humidification – An Economic Evaluation*) on compressed-air energy storage with humidification. Project encompassed: (i) technology evaluations and financial modeling; (ii) preliminary system design, including layout drawings and conceptual equipment arrangements; (iii) capital cost estimates for this and competing technologies; (iv) a market price study for electricity; (v) fuel cost estimates; and (vi) development of a pro forma for each technology.

Lockheed Martin

2019 | 2 MW/4 MWh | Illinois | Provided detailed design services for a BESS for ComEd.

PacifiCorp

2005 | Provided owner’s engineering services, including development of a CAES conceptual design.

U.S. Department of Energy, EPRI, Public Service Company of Indiana, Westinghouse Electric Company

1982 | Conducted a three-year study of CAES and prepared a report (*Compressed Air Energy Storage Preliminary Design and Site Development Program in an Aquifer*). Research included project coordination,
power system studies, geotechnical reviews and designs, site study and selection, turbine design, BOP designs, cost estimating, schedule preparation, licensing assessment, and environmental impact studies.

**Vistra Energy**

2018–2019 | 9.9 MW/42 MWh | Texas | Provided owner’s engineering services for a BESS that was added to an existing 180-MW solar facility.
Sargent & Lundy has extensive experience with hybrid power plants, including the planning and design of the following complex projects:

**Selected Recent Project Experience**

**Confidential Clients**

- **2020–2022 | Maryland** | Developed a feasibility report to describe energy efficiency upgrade opportunities and upgrades completed within the past five years. Estimated the cost for full system implementation with a budgetary breakdown by final engineering and design costs, equipment costs, labor costs, permitting and inspection fees, utility interconnection fees, site preparation costs, installation costs, and final commissioning costs.

- **2020 | 500+ MW | Mongolia** | Provided technical advisory support for a client considering multiple 500+ MW hybrid solar-plus-wind plants with supplemental grid support to provide consistent power to a mine. Scope included a review of technical and commercial concept proposals as well as guidance in next steps of the development process.

- **2019 | Midwestern United States** | Studied a diesel generator-based microgrid at an existing casino integrated into an existing solar PV field.

- **2018–2019 | Eastern United States** | Performed a technical feasibility study for a large East Coast utility to support the addition of battery energy storage. Studied adding storage to existing solar projects and thermal power plants.

- **2018–2019 | 400 MW | Texas** | Provided owner’s engineering services to support conceptual layout design optimization, tracker technology selection, and EPC bid solicitation for a 400-MW solar and battery storage project.
ComEd

- 2019 | 2 MW/4 MWh | Illinois | Bronzeville Community Microgrid | Provided detailed design services for the project’s BESS portion.
- 2019 | Illinois | Provided detailed design services for the integration of existing solar and wind distributed energy resources using ComEd’s distributed energy resource management system.

PNE USA, Inc.

- 2022–2023 | Provided a conceptual general arrangement for a solar, BESS, and hydrogen facility that depicted the placement of PV modules and central inverters. Submitted a general arrangement drawing that included the Plant Predict output, estimated substation location, estimated generator tie-line route, and POI. The sites were as follows:
  - 300 MW | Texas | Daniels Creek Solar Project
  - 150 MW | Oregon | Old Geyser Solar Project
  - 50 MW | Arizona | Sand Tank Solar Project
- 2022–2023 | 50 MW | Illinois | Tenmile Creek | Provided preliminary design services for a solar, hydrogen, and BESS project. Provided a general arrangement showing these facilities and basic details including inverter blocks and roads for the site. Prepared a preliminary design single-line diagram showing the project overall and the systems of the hydrogen production facility.
- 2022–2023 | 199 MW | Utah | Red Butte | Provided an update to a previously developed conceptual design (site layout and single-line diagram) to reflect a preliminary design stage. Updated the general arrangement drawing to show a 100-MW, 4-hour BESS, a 50-MWac hydrogen production facility, and to show basic details including inverter blocks and roads for the site. Prepared an updated preliminary design single-line diagram showing the project overall and the systems of the hydrogen production facility.
- 2022–2023 | 150 MW | New Mexico | Flat Top | Provided preliminary design services for a solar, hydrogen, and BESS project. Provided a general arrangement showing these facilities. Prepared a preliminary design single-line diagram showing the project overall and the systems of the hydrogen production facility.
- 2022 | Provided standard layouts for a BESS and hydrogen production facility that will be integrated with a solar PV project.

Vistra Energy

2017–2018 | 180 MW | Texas | Upton 2 Solar Project | Provided owner’s engineering services to support adding battery energy storage. Services included battery technology advisory services, cost estimates, and preliminary electrical design.
**Additional Project Experience**

**Agrifos Fertilizer**


**American Capital Energy & Infrastructure**

2014 | Senegal | Performed a renewable energy integration assessment for the countrywide electric grid to assist the client with their evaluation of a wind power project acquisition. Assessed the existing generators on the system and their reserve capabilities.

**CMS Generation**

2000 | Performed a technology survey and analysis investigation of commercially available renewable energy technologies for the client to incorporate into their long-term power generation strategic plan. The renewable energy technologies surveyed included wind power, biomass, geothermal, solar thermal, and solar PV technologies.

**City of Ames**

2004 | Iowa | Developed a recommended resource plan that identified the generation resources required to meet the forecast electricity needs of Ames Electric Services’ customers through 2025. Resource options included renewable energy resources that would be appropriate for the Green Choice program, primarily biomass and wind along with efficient, low-emission generating technologies like natural gas or other fuels.

**Confidential Clients**

- 2016 | 120 MW | California | Provided development support, conceptual design, and owner’s engineering services for a planned hybrid power plant using solar PV and thermal generation.
- 2013 & 2015 | Northeastern United States | Managed the power supply planning process for a utility client. Reviewed and evaluated over 50 power supply and load reduction bids. Bids included technologies such as combustion turbines, reciprocating engines, energy storage, microgrids, and demand-side projects.

**Domtar Paper**

2018 | Pennsylvania | Johnsonburg Mill | Performed an electrical analysis for load flow, a short-circuit study, a transient analysis, and a relay coordination study to support a proposed realignment of the mill electrical loads to a single utility feed. Evaluated load shedding schemes to allow the mill to island the electrical system via local generation.
InterGen

2008 | Conducted a feasibility study of a solar retrofit for a 501F 1x1 combined-cycle unit. The CSP technologies addressed were parabolic trough, power tower, and compact linear Fresnel receiver. Identified relevant advantages and disadvantages of each type of system. Evaluation areas included steam conditions achievable, technology maturity, comparative capital and O&M costs, and equipment availability.

NextEra Energy Resources, LLC

2020–2022 | 50 MW + 30 MW/1200 MWh | Oregon | Wheatridge Solar + Storage Project | Provided independent engineering due diligence services in support of project financing for a renewable energy portfolio. Assessed the site and construction activities for each project in the portfolio through desktop reviews and site visits. Reviewed the design, selection of major equipment, environmental and permitting efforts, financial performance, and key contracts for each project. Performed independent energy yield assessments.

NIPSCO

2013 & 2015 | Provided cost and performance estimates for various power generation and energy storage systems to support the client’s resource planning activities.

San Diego Gas & Electric

2003 | Provided consultation regarding new power supply resources, including renewable generation, fossil generation, and demand-side resources. Provided consulting support through the evaluation of options, contract negotiation, and utility commission filings for PPAs and turnkey plant purchases.

Southern California Edison

2005 | 1580 MW | Mohave Generating Station | Prepared a study of alternatives for replacing or complementing electrical capacity generation of the client’s share of the project in response to a California Public Utilities Commission (CPUC) order. Evaluation included solar, wind, other renewables, demand-side management and energy efficiency, integrated solar combined-cycle technology, and combined-cycle, natural gas generation.

Unilever

2008–2009 | California | Performed a study of energy usage, boiler replacement options, and onsite renewable energy alternatives for the client’s industrial facility. The evaluation included combined heat and power, solar PV, and energy efficiency technology.

Value Recovery Holding

- 2017 | Developed a modeling tool for the integration and optimization of backup generators for microgrids.
• 2015–2016 | Reviewed sizing and conceptual design of a microgrid planned for installation at a US Army base. Project included solar PV, liquid fuel engines, and battery energy storage.
Selected Sargent & Lundy Renewable Energy Publications and Presentations

- “Energy Assessment & Independent Engineering Review for Wind Project Partial Repower,” authored by E. Soderlund (Sargent & Lundy) and J. O’Connor (ArcVera Renewables), presented by D. Jolivet (Sargent & Lundy) and J. O’Connor, EUCI Conference, San Diego, California, February 2019.

• “Everything You Always Wanted to Know About Wind Power Purchase Agreements,” presented and authored by G. Rainey and T. Kantarek, AWEA WINDPOWER Conference, Las Vegas, Nevada, May 2014.


These and other papers are available upon request.
# Acronyms and Abbreviations

<table>
<thead>
<tr>
<th>Acronym or Abbreviation</th>
<th>Definition</th>
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<tbody>
<tr>
<td>AWEA</td>
<td>American Wind Energy Association</td>
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<tr>
<td>BESS</td>
<td>battery energy storage system</td>
</tr>
<tr>
<td>BFB</td>
<td>bubbling fluidized bed</td>
</tr>
<tr>
<td>BOOT</td>
<td>build, own, operate, and transfer</td>
</tr>
<tr>
<td>BOP</td>
<td>balance of plant</td>
</tr>
<tr>
<td>CAES</td>
<td>compressed-air energy storage</td>
</tr>
<tr>
<td>CFB</td>
<td>circulating fluidized bed</td>
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<tr>
<td>CSP</td>
<td>concentrating solar power</td>
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<tr>
<td>CT</td>
<td>combustion turbine</td>
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</tbody>
</table>
| DEWA                    | Dubai Electricity and Water Authority  
                          [United Arab Emirates] |
| EPC                     | engineering, procurement, and construction |
| EPRI                    | Electric Power Research Institute |
| GE                      | General Electric |
| HEPP                    | hydroelectric power plant |
| HRSG                    | heat recovery steam generator |
| HTF                     | heat transfer fluid |
| IPP                     | independent power producer |
| IRS                     | Internal Revenue Service |
| LCOE                    | levelized cost of electricity |
| LFG                     | landfill gas |
| NO\textsubscript{x}      | nitrogen oxide |
| NREL                    | National Renewable Energy Laboratory  
                          [U.S. Department of Energy] |
<p>| O&amp;M                     | operations and maintenance |
| P&amp;H                     | Patrick &amp; Henderson |
| PC                      | pulverized coal |
| PM                      | particulate matter |</p>
<table>
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<th>Acronym or Abbreviation</th>
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<tbody>
<tr>
<td>POI</td>
<td>point of interconnection</td>
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<tr>
<td>PPA</td>
<td>power purchase agreement</td>
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<tr>
<td>PV</td>
<td>photovoltaic</td>
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<tr>
<td>QA/QC</td>
<td>quality assurance and quality control</td>
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<tr>
<td>RDF</td>
<td>refuse-derived fuel</td>
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<tr>
<td>RFP</td>
<td>Request for Proposal</td>
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<tr>
<td>SCADA</td>
<td>supervisory control and data acquisition</td>
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<tr>
<td>WTE</td>
<td>waste-to-energy</td>
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<tr>
<td>WTG</td>
<td>wind turbine generator</td>
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</table>
### Clean Hydrogen Hub Feasibility Studies

Providing engineering services to a confidential client developing a clean hydrogen hub in the United States. Hub will include hydrogen generation via both electrolysis and the partial oxidation of natural gas with carbon capture and sequestration. Hydrogen will be fed to an ammonia synthesis unit for clean ammonia production. Current work includes development of a design basis for the facilities, feedstock analyses, general arrangements of hydrogen facilities, conceptual process design, conceptual electrical systems design, and cost estimating.

<table>
<thead>
<tr>
<th>Client</th>
<th>Location</th>
<th>Facility Type</th>
<th>Major Equipment</th>
<th>Schedule</th>
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</thead>
<tbody>
<tr>
<td>Confidential</td>
<td>Confidential, U.S.</td>
<td>Clean Hydrogen Hub</td>
<td>Partial Oxidation Unit with CCS, Electrolyzers, Ammonia Synthesis</td>
<td>Q1 2023–Ongoing</td>
</tr>
</tbody>
</table>

### Clean Hydrogen Hub Fatal Flaw Analysis

Providing engineering services to a confidential client developing a clean hydrogen hub in the United States. Hub will include hydrogen generation via electrolysis, compression, pipelines, and underground storage. Current work includes a fatal flaw analysis of the site based on factors such as available land and the suitability for the clean hydrogen production and storage facilities. The project also includes permitting evaluation for the site.

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<td>Confidential</td>
<td>Confidential, U.S.</td>
<td>Clean Hydrogen Hub</td>
<td>Electrolyzers, Gaseous Storage, Compressor(s), Underground Storage</td>
<td>Q1 2023–Ongoing</td>
</tr>
</tbody>
</table>

### Clean Hydrogen Hub Conceptual Design and Study

Providing engineering services to a confidential client developing a clean hydrogen hub in the United States. Hub will include multiple locations with hydrogen generation, storage, and vehicle fueling throughout the region. Current work includes development of a design basis for the facilities, feedstock analyses, general arrangements of hydrogen facilities, conceptual process design, conceptual electrical systems design, and cost estimating.

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<td>Clean Hydrogen Hub</td>
<td>Electrolyzers, Liquefaction, Liquid Storage, Gaseous Storage, Vehicle Fueling</td>
<td>Q1 2023–Ongoing</td>
</tr>
</tbody>
</table>

### Clean Hydrogen Facility Project

Providing engineering services to a confidential client developing a 35-MW hydrogen facility with onsite renewable power generation via solar PV. Current work includes pre-FEED and FEED studies evaluating the solar PV system design, feedstock analysis, general arrangement of hydrogen facility, process design, electrical systems design, and cost estimating. Studies also include permitting analysis.

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<tbody>
<tr>
<td>Confidential</td>
<td>Confidential, U.S.</td>
<td>35-MW Solar PV and Hydrogen Production Facility</td>
<td>Solar PV, Electrolyzers, Liquefaction, Liquid Storage</td>
<td>Q1 2023–Ongoing</td>
</tr>
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<td>Client</td>
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<tr>
<td>Confidential</td>
<td>Multiple Confidential, U.S. Locations</td>
<td>Large-Scale Nuclear Hydrogen Production Facility</td>
<td>Nuclear Power Plant, Electrolyzers, Storage, Compressor(s)</td>
<td>Q1 2023–Ongoing</td>
</tr>
</tbody>
</table>

**Large-scale nuclear hydrogen facility study**

Providing engineering services to a confidential client developing a large-scale clean hydrogen facility co-located with an existing nuclear power plant. Study includes power sourcing study, feedstock analysis, general arrangement of hydrogen facility, and technoeconomic analysis of offtake possibilities. Evaluating all forms of electrolysis for optimal hydrogen production efficiency.

| Confidential                  | Confidential, U.S.          | Green Hydrogen Production Facility                  | Onshore Wind, Solar PV, Electrolyzers                                           | Q1 2023–Ongoing |

**Power sourcing study for green hydrogen facility**

Conducting a power sourcing study for a gigawatt-scale hydrogen production facility. This study includes definition of the power inputs required for a hydrogen production facility and land area requirements. Assessing sourcing power from behind-the-meter greenfield renewable generation, grid supply, and acquisition of existing renewable developments.

| Confidential                  | Confidential, U.S.          | Clean Data Center with Hydrogen                     | Data Center, Hydrogen Fuel Cell, Liquid Hydrogen Storage                         | Q4 2022–Ongoing |

**Clean hydrogen data center project**

Providing detailed engineering services to a confidential client building a clean data center powered by hydrogen. System includes a stationary PEM fuel cell, liquid hydrogen storage, hydrogen vaporizers, and all associated safety systems. Sargent & Lundy is responsible for the detailed design of the hydrogen system, including layouts, piping design, and safety system design. Sargent & Lundy will also be supplying commissioning services for the unit.

| Confidential                  | Confidential, U.S.          | Clean Energy Hub                                    | SMR/ATR with CCS, Electrolyzers, Renewables                                     | Q4 2022–Ongoing |

**Feasibility study for clean energy hub project**

Providing engineering services to a confidential client developing a clean energy hub around an existing gas treatment facility. This clean energy hub is expected to include renewable power generation, hydrogen production via electrolysis, and hydrogen production via steam methane reforming (SMR) or autothermal reforming (ATR) with carbon capture and storage. Scope includes a design basis, PFDs, layouts, and cost estimating support.

| Confidential                  | Multiple Confidential, U.S. Locations | Methane Pyrolysis Unit, Ammonia Synthesis Unit       | Q4 2022–Ongoing |

**Independent engineering services for methane pyrolysis projects**

Providing independent engineering services to a confidential client working on several methane pyrolysis projects in the U.S. Scope includes an overview of the methane pyrolysis technology, as well as several of the completed projects as benchmarking for the client to predict the performance of a facility expansion. Also performing a high-level design review of the major systems for compliance with industry standards and best practices.
### Hydrogen Experience
Owner's Engineering, Studies, Technical Oversight

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<td>Confidential</td>
<td>Confidential, U.S.</td>
<td>Solar PV</td>
<td>Electrolyzers, Storage, Compressor(s), Offloading</td>
<td>Q4 2022–Ongoing</td>
</tr>
</tbody>
</table>

#### 25-MW green hydrogen production facility feasibility study
Performing a feasibility study related to the installation of a 25-MW green hydrogen production facility coupled with solar PV power resources. The study includes design of balance-of-plant (BOP) systems around a 25-MW electrolyzer system, including electrical interconnects, water infrastructure, and more. The study will also investigate scale-up to a 100-MW capacity in the future. Feasibility study also encompasses permitting screening, including determination of permits needed, timelines for approvals, and associated costs, as well as capital cost estimating.

| Confidential | Confidential, U.S. | Green Ammonia | Electrolyzers, Storage, Compressor(s), Ammonia Synthesis, ASU | Q4 2022–Ongoing |

#### Fatal flaw analysis of hydrogen production and green ammonia facility
Performing a fatal flaw analysis for a ~600-MW renewable-powered hydrogen production facility co-located with a 500-kTPA green ammonia facility for the export of green ammonia. The study involves investigations into feedstock availability, site feasibility, and basic permitting for the system. Also includes Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) greenhouse gas emissions evaluation for the system, as well as capital expenditures (CapEx) and operating expenses (OpEx) estimates.

| Confidential | Confidential, U.S. | Multiple Locations | Solar PV, Battery Energy Storage | Electrolyzers, Storage, Compressor(s), Offloading | Q4 2022–Q1 2023 |

#### Integrated solar PV, battery energy storage system (BESS), and hydrogen facility layouts
Providing site-specific layouts for 10-MWac, four-hour BESS, and 10-MWac hydrogen production facilities, both integrated with solar PV. The hydrogen production facility layouts include electrolyzers, control room, water treatment system, hydrogen storage, compression system, hydrogen offloading, and other balance-of-plant (BOP) systems.

| Confidential | Confidential, U.S. | Hydrogen Testing Facility | Storage, Offloading | Q3 2022–Q3 2022 |

#### Code assessment and fatal flow assessment for retrofit of testing facility for hydrogen
Performed a codes and standards analysis and a fatal flaw analysis for adding hydrogen fueling infrastructure to a testing facility. The added hydrogen would enable the testing of internal combustion engines (ICEs) on blended fuels with varying amounts of hydrogen. Investigation included tube trailer siting, piping layout, and HVAC modifications needed to support the addition of hydrogen infrastructure.

| Confidential | Confidential, U.S. | Various | Electrolyzers, Storage, Compressor(s), Gas Turbines | Q2 2022–Ongoing |

#### Framework for green hydrogen production, storage, and use for power buffering
Assisting a confidential client with developing a framework for green hydrogen production, storage, and use as a fuel for gas turbines in power generation to serve as short-term or seasonal grid buffering. The framework will serve as a starting point for identifying, sizing, and configuring system components based on geographical location and power output. The framework will be presented in the form of an interactive website.
## Design guide for hydrogen at nuclear power plants

Assisting a confidential client with developing a guideline for the planning, design, and project execution of a hydrogen plant at existing nuclear power plants. This guide will cover the planning and development of integrating both low-temperature electrolysis (LTE) and high-temperature electrolysis (HTE) into existing pressurized water reactors (PWRs) and boiling water reactors (BWRs).

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<td>Confidential, U.S.</td>
<td>Nuclear</td>
<td>Electrolyzers, Storage, Compressor(s), Offloading</td>
<td>Q2 2022–Ongoing</td>
</tr>
</tbody>
</table>

## Feasibility study for high-temperature electrolysis at a nuclear power plant

Investigated the feasibility and cost of a hot electrolysis facility (SOECs) at an existing nuclear power plant. The study involved approximately 50 MW of electrolysis, hydrogen compression, hydrogen storage, and tube trailer offloading for the facility. The study also included behind-the-meter work at the nuclear plant, as well as integration with the nuclear plant's steam cycle.

| Confidential    | Confidential, U.S.  | Nuclear       | Solid Oxide (SOEC) Electrolyzers, Storage, Compressor(s) | Q2 2022–Q4 2023|

## Green hydrogen modeling

Developed a model that blends both economic and technical parameters associated with green hydrogen production. The final model was used to compare and optimize different green hydrogen production plant configurations, operational practices, and other technical considerations for their impact on the levelized cost of hydrogen (LCOH). The modeling focused on different sizes of proton exchange membrane (PEM) electrolyzers tied to solar PV facilities for the creation of green hydrogen.

| Confidential    | Not Applicable      | Solar PV      | Electrolyzers, Storage, Compressor(s), Offloading      | Q2 2022–Q3 2022|

## Layouts for battery energy storage system (BESS) and hydrogen production integrated with solar PV

Provided standard layouts for a 100-MWac, four-hour BESS, and 50-MWac hydrogen production facility, both intended to be integrated with a reference 150-MWac solar PV project. The hydrogen production facility layout will include electrolyzers, control room and water treatment system, hydrogen storage and compression system, hydrogen rejection system, and hydrogen offloading.

| Confidential    | Not Applicable      | Solar PV      | Electrolyzers, Storage, Compressor(s), Offloading      | Q2 2022–Q3 2022|
## Hydrogen Experience
**Owner’s Engineering, Studies, Technical Oversight**

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<tr>
<td>Idaho National Laboratory (INL)</td>
<td>--</td>
<td>Nuclear</td>
<td>Solid Oxide (SOEC) Electrolyzers, Storage, Compressor(s)</td>
<td>Q1 2022–Ongoing</td>
</tr>
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</table>

### Nuclear plant preconceptual 10 CFR 50.59 evaluation for large-scale hydrogen production facility

Providing licensing guidance to INL for the coupling of nuclear power plants with large-scale, high temperature electrolysis hydrogen production facilities. Using the 100-MW preconceptual design from a previous report, an evaluation is performed for a reference plant to observe the applicability of the 10 CFR 50.59 process for a nuclear integrated hydrogen production facility modification. Site-specific considerations and general limitations are provided for plant reference.

| Idaho National Laboratory (INL) | -- | Nuclear | Solid Oxide (SOEC) Electrolyzers, Storage, Compressor(s) | Q1 2022–Ongoing |

### Nuclear plant preconceptual design for large-scale hydrogen production facility

Providing preconceptual design support for INL relating to coupling nuclear power plants with large-scale, high-temperature electrolysis hydrogen production facilities. This includes evaluation of the required modifications needed to divert thermal and electrical energy to high-temperature electrolysis facilities. Steam extraction and electrical transmission designs are developed for two independent hydrogen facilities, requiring nominal power inputs of 100 MW and 500 MW, respectively. The preconceptual designs are intended to serve as feasibility studies for utilities considering such modifications.

| Confidential | Confidential, U.S. | Combined Cycle | Proton Exchange Membrane (PEM) Electrolyzers, Storage, Compressor(s), Gas Turbine | Q1 2022–Ongoing |

### Owner’s engineering for hydrogen production facility

Providing owner’s engineering services to a utility client for the design of a hydrogen production facility co-located with an existing combined cycle power plant. Our scope includes conceptual design of a 20-MW hydrogen generation facility, encompassing gaseous hydrogen storage, compression, and blending systems. Sargent & Lundy is also assisting with long-lead procurement, cost estimating, facility layouts, and the development of an EPC scope of work.

| Confidential | Various, U.S. | Solar PV | TBD | Q1 2022–Ongoing |

### Owner’s engineering for various solar PV facilities

Providing owner’s engineering services to a solar PV developer with renewable energy facilities across the U.S. Our scope includes conceptual designs of hydrogen generation facilities, energy modeling and forecasting, and siting studies for hydrogen generation capacities from 25 MW to 200 MW, including liquefaction and trucking terminals.

| Confidential | Confidential | N/A | N/A | Q1 2022–Ongoing |

### Hydrogen code assessment

Providing a hydrogen code assessment for a confidential client related to the Spanish Islands off the coast of Africa. The work is focused on identifying key hydrogen-related specifications for the islands to prepare for potential projects in the future.
Hydrogen market forecasting tool
Sargent & Lundy was contracted by a large investment firm to support the development of a supply and demand analysis of hydrogen and electricity based on future decarbonization initiatives in home heating and heavy-industry sectors. The client requested Sargent & Lundy's assistance in developing a Microsoft Excel-based model and a data repository of industry data. The model will enable the client to forecast future hydrogen demand for electricity generation based on decarbonization sensitivities. Sargent & Lundy is also preparing a corresponding white paper that will provide supplemental qualitative discussion on various topics in hydrogen markets, home heating, and heavy-industry sectors.

Feasibility study for green ammonia facility
Conducted a confidential feasibility study for a green ammonia facility in western Africa. This facility would use excess electricity from a nearby hydroelectric power source to feed alkaline electrolysis on the scale of 240 MW. The hydrogen produced would then feed into 500 tons per day (tpd) ammonia synthesis unit to make green ammonia for distribution. The project also included an air separation unit (ASU) to feed the ammonia synthesis process.

Engineering support for hydrogen co-firing demonstration in large gas turbines
Provided engineering services related to a successful demonstration blending hydrogen with natural gas in large gas turbines up to 20% by volume of hydrogen. Gas turbines included dry low-NOx (DLN) burners and was the largest demonstration of this type to date. Also provided code reviews, design reviews, and hydrogen supply equipment inspections.

Feasibility study for co-firing of hydrogen in advanced-class gas turbines at new combined cycle facility
Performed a study that included the preliminary engineering, design, and cost considerations of blending hydrogen with natural gas and co-firing in advanced-class gas turbines at concentrations of 30 vol% and 100 vol%.

Owner’s engineering for virtual hydrogen pipeline
Provided owner’s engineering services for design of a new virtual hydrogen pipeline facility at an existing renewable energy facility of greater than 300 MW. The facility design included 15 MW of PEM electrolyzers with corresponding hydrogen compression and trailer offloading. Sargent & Lundy assisted with activities such as the conceptual design, long-lead equipment procurement, EPC contract development, and overall project execution oversight.
### Hydrogen Experience
**Owner’s Engineering, Studies, Technical Oversight**

<table>
<thead>
<tr>
<th>Client</th>
<th>Location</th>
<th>Facility Type</th>
<th>Major Equipment</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confidential</td>
<td>Confidential, U.S.</td>
<td>Microgrid / Hydrogen Fueling</td>
<td>Proton Exchange Membrane (PEM) Electrolyzers, Storage, Compressor(s), H₂ Fueling, Fuel Cell</td>
<td>Q4 2021–Q4 2022</td>
</tr>
</tbody>
</table>

**Resiliency study related to variable renewable energy sources coupled with grid electricity to provide resilient power and hydrogen fueling capabilities**

Conducted study that focused on both 100-kW and 1-MW electrolyzer systems with differently sized components incorporated within an existing microgrid to produce hydrogen for energy storage and hydrogen fueling stations. These components include electrolyzers, stationary fuel cells, hydrogen storage, hydrogen fueling stations, and all associated balance-of-plant (BOP) supporting systems. Activities included equipment sizing, systems design, and cost estimating for the systems.

| Confidential | Confidential, U.S. | Power-to-Gas | PEM Electrolyzers, Storage, Compressor(s) | Q4 2021–Q2 2022 |

**Front-end engineering and design (FEED) study related to a power-to-gas hydrogen demonstration plant for distributed energy storage around renewable assets**

Conducted study that included engineering, design, and cost estimating for a facility that will produce hydrogen via 5-MW of PEM electrolysis driven by renewable wind power and store the hydrogen on site to be sold to the hydrogen market. The study encompassed hydrogen compression and gaseous hydrogen storage in tube racks along with a filling station for mobile tube trailers. This first-of-a-kind power-to-gas demonstration would produce carbon-free hydrogen for sale when the grid does not require all of the power produced at the site.

| Confidential | Confidential, U.S. | Distributed Generation | Small Modular Reactor (SMR)-Based Hydrogen Generation | Q4 2021–Q1 2022 |

**Technology due diligence of novel SMR-based distributed hydrogen generation technology**

Sargent & Lundy was contracted by a potential investor to perform a technology due diligence of a skid-mounted distributed hydrogen generation system capable of generating 1,000 kg/day of hydrogen utilizing a proprietary SMR technology. Sargent & Lundy’s review focused on process efficiency, output, and safety features to ensure that the skid was suitable for any site or environment. In addition to reviewing the technical aspects of the skid, Sargent & Lundy was tasked with reviewing the financial model prepared by the manufacturer. The manufacturer prepared a single representative financial model for the skid, which included capital costs, O&M costs, and consumable costs. Sargent & Lundy was tasked with confirming that the financial model parameters were adequate for any site or environment in which the skid may operate. Sargent & Lundy also prepared a technical and financial comparison of the skid against existing commercially available hydrogen technologies, which included SMR, electrolysis, and fuel cell technologies.

| Confidential | Confidential, U.S. | Commercial Trucking Fleet | PEM Electrolyzers, Storage, Compressor(s) | Q4 2021–Q1 2022 |

**Development of commercial Class 8 trucking fleet zero-emission/decarbonization transition utilizing multiple technologies, including battery electric and hydrogen fuel cell vehicles**

Provided energy assessments and conducted modeling for the fleet conversion to evaluate new energy needs to develop the corresponding infrastructure and facilitate power purchase agreements, as well as onsite renewable generation where feasible. The facilities are planned to include 95% of fleet fueling on site at regional distribution centers with onsite hydrogen production and storage.
## Engineering for commercial-scale hydrogen production and storage project collocated with existing simple cycle facility for hydrogen cofiring in a gas turbine

The project includes 2 MW of renewable solar PV-powered PEM electrolyzers, hydrogen compression, gaseous aboveground storage, and blending of hydrogen with natural gas for use in an existing gas turbine. Hydrogen will be stored on site in stationary tube bundles and be able to be blended into the gas turbine at varying concentrations. The project includes other aspects of the facility, such as integration with the plant’s water treatment system, a cooling system, hydrogen detection and monitoring, and fire protection.

<table>
<thead>
<tr>
<th>Client</th>
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</thead>
<tbody>
<tr>
<td>Confidential</td>
<td>Confidential, U.S.</td>
<td>Simple Cycle</td>
<td>PEM Electrolyzer, Storage, Compressor(s), Gas Turbine</td>
<td>Q3 2021–Ongoing</td>
</tr>
</tbody>
</table>

## Large-scale hydrogen production and storage

Providing owner’s engineering services for a large integrated hydrogen production and geologic storage project. The project consists of more than 200 MW of grid-connected electrolyzers with corresponding hydrogen compression and geologic storage for seasonal hydrogen energy storage.

| Confidential    | Confidential, U.S.| Generation and Storage | Advanced-Class Gas Turbine, Alkaline Electrolyzers, Geologic Storage | Q3 2021–Ongoing |

## Pre-FEED study and conceptual design for large-scale hydrogen liquefaction and distribution terminal

Conducted study that encompassed the hydrogen liquefaction technology selection, process design, and storage, as well as the truck terminal. The study consisted of conceptual engineering, design, and cost estimating related to the 30-tpd production facility.

| Confidential    | Confidential, International | Liquid Hydrogen Terminal | Hydrogen Liquefaction, Hydrogen Filling Station/Terminal | Q2 2021–Q3 2021 |

## Large-scale power-to-ammonia facility

Providing lender’s technical advisory (LTA) services for development of a facility that will use renewable solar PV resources to power the production of hydrogen via electrolysis. The hydrogen will then be synthesized into green ammonia using the Haber-Bosch process for distribution. We are also reviewing project documents on behalf of the client to ensure the safe and compliant design of the facility.

<p>| Confidential    | Confidential, International | Power-to-Ammonia | Solar PV, Electrolyzers, Ammonia Production | Q1 2021–Ongoing |</p>
<table>
<thead>
<tr>
<th>Client</th>
<th>Location</th>
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<th>Major Equipment</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confidential</td>
<td>Confidential, U.S.</td>
<td>Nuclear Pressurized/Boiler Water Reactor (PWR)</td>
<td>High-Temperature Steam Electrolysis (HTSE)</td>
<td>Q1 2021–Ongoing</td>
</tr>
<tr>
<td>Confidential</td>
<td>Confidential, U.S.</td>
<td>Combined Cycle</td>
<td>Advanced-Class Gas Turbines, PEM Electrolyzers</td>
<td>Q1 2021-Q1 2022</td>
</tr>
<tr>
<td>EPRI/ NYPA</td>
<td>Long Island, New York</td>
<td>Simple Cycle</td>
<td>GE, LM6000</td>
<td>Q1 2021 -Ongoing, Q4 2021 (12 months)</td>
</tr>
</tbody>
</table>

**High-temperature steam electrolysis (HTSE) equipment at nuclear facility**

Supporting the client’s grant application to the DOE for the installation of an HTSE skid. Sargent & Lundy’s work includes conceptual plant interconnection designs and cost estimates for both a BWR and a PWR installation of a demonstration-sized HTSE skid (200-kW to 1-MW). The conceptual interconnect designs encompass both thermal and electrical interfaces, including the unique considerations needed for either a PWR or BWR. Also assisting the client with the development of a purchase specification related to the HTSE skid, now roughly 300 kW in size. Project includes a study of capturing and compressing the hydrogen for offloading or other use on site.

**Conceptual design for green hydrogen facility powered by renewable solar PV power at advanced-class combined cycle facility**

Conducted study that encompassed the compression, storage, and blending of hydrogen with natural gas for use in an advanced-class combined cycle facility. The study tasks consisted of conceptual engineering, design, and cost estimating related to the 25-MW production facility. Hydrogen is stored on site in stationary tube bundles and is blended into the gas turbines at varying concentrations. The project encompassed other aspects of the facility, such as the electrolysis building design, hydrogen detection and monitoring, and fire protection.

**Hydrogen cofiring demonstration plant at simple cycle facility**

Provided owner’s engineering services for this project being executed in conjunction with owner NYPA, research partner EPRI, and original equipment manufacturer (OEM) General Electric (GE). Our scope included providing technical oversight on behalf of EPRI, to ensure the project design is executed properly, with specific focus on safety. We performed a targeted review of all safety requirements, code requirements, OEM requirements, and utility procedural/safety requirements. Our scope also included providing quality control inspections for all fabricated components.

Sargent & Lundy also provided additional engineer-of-record services directly to NYPA for this project. These services included additional oversight of the project to enable Sargent & Lundy to provide certifying documentation that the project and the work of the engineering and design partners is being performed in accordance with applicable codes, standards, etc. We further provided certifying documentation to the NYPA codes group in support of NYPA’s internal certification process for obtaining building permits.

The intent of the project was to perform a short-duration hydrogen cofiring demonstration from 0-30 vol% hydrogen to gather technical data from real-world testing of the existing equipment’s cofiring capabilities. The data are expected to be used by the OEM to improve technical knowledge of the impacts of hydrogen cofiring on the equipment. This project is first-of-its-kind for proving hydrogen cofiring capacity in an existing combustion turbine, which was not designed to accommodate hydrogen-blended fuels.
Hydrogen Experience
Owner’s Engineering, Studies, Technical Oversight

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<tr>
<td>Confidential</td>
<td>Confidential, U.S.</td>
<td>Power-to-Power</td>
<td>PEM Electrolyzer, Fuel Cell</td>
<td>Q1 2021–Q3 2021</td>
</tr>
</tbody>
</table>

Pre-FEED study and conceptual design for power-to-power hydrogen demonstration plant for distributed energy storage around renewable assets

Conducted study that included engineering, design, and cost estimating for a facility that will produce hydrogen via 2.5 MW of PEM electrolysis driven by renewable wind power and be stored on site for dispatched use in a fuel cell. The study encompassed hydrogen compression and gaseous hydrogen storage in tube trailers. This first-of-a-kind power-to-power demonstration would produce carbon-free hydrogen for energy storage to be converted back into power with the fuel cell when required by grid demands.

<table>
<thead>
<tr>
<th>Confidential</th>
<th>Confidential, U.S.</th>
<th>Combined Cycle</th>
<th>Advanced-Class Gas Turbines</th>
<th>Q4 2020–Q2 2022</th>
</tr>
</thead>
</table>

Engineering study for mixing and cofiring of pipeline-supplied hydrogen in advanced-class gas turbines at new combined cycle facility

Conducted study that included the preliminary engineering, design, and cost estimating of all upstream BOP infrastructure for hydrogen and natural gas conditioning, blending of hydrogen with natural gas, and more, before being sent to the gas turbines. The study also assessed the blending of hydrogen at an initial concentration of 30 vol% and eventual transition to 100 vol% with the focus on the impacts to the fuel delivery system.

<table>
<thead>
<tr>
<th>Confidential</th>
<th>Confidential, U.S.</th>
<th>N/A</th>
<th>Stationary Thermal Application</th>
<th>Q4 2020–Q1 2022</th>
</tr>
</thead>
</table>

Independent witnessing for hydrogen thermal application pilot project

Provided independent witnessing for a business founded several years ago to produce hydrogen for stationary thermal applications but with higher calorific value and at lower cost than existing hydrogen production technologies. Scope included witnessing and reporting on pilot project test for investors.

<table>
<thead>
<tr>
<th>EPRI</th>
<th>Confidential, U.S.</th>
<th>Simple Cycle</th>
<th>GE, LM6000</th>
<th>Q4 2020–Q2 2021 (6 months)</th>
</tr>
</thead>
</table>

Engineering study for multiphase hydrogen cofiring project planning initiative

Conducted study that consisted of a two-phase execution plan for hydrogen cofiring at an existing simple cycle peaking plant. The study considered initial execution of the project for proof-of-concept testing utilizing truck/trailer-delivered hydrogen, onsite blending, and cofiring of hydrogen up to a specified percentage (as limited by the existing gas turbine technology). The study also considered long-term execution, including onsite generation of hydrogen via 12.5-MW of PEM electrolyzers, onsite storage of hydrogen, and cofiring at two percentages (again, as limited by the existing gas turbine technology). Both phases of the project required evaluation of technical impacts and cost implications. For cost control, demonstration-phase systems and infrastructure were designed for maximum reuse during long-term execution to support onsite generation, storage, blending, cofiring, etc.

<table>
<thead>
<tr>
<th>Confidential</th>
<th>Confidential, U.S.</th>
<th>Nuclear PWR</th>
<th>PEM Electrolysis</th>
<th>2019–Ongoing</th>
</tr>
</thead>
</table>

Multiphase engineering study for coupling of nuclear power and carbon-free hydrogen production

Conducting study that focuses on conceptual engineering to couple a nuclear power plant with a PEM electrolyzer-driven green hydrogen production pilot as a proof-of-concept for nuclear-powered hydrogen production. Work covers the engineering change packages associated with the electrical interconnect, control room modifications, and the hydrogen island design. Hydrogen island includes 2 MW of PEM electrolysis, compression, and offtake to tube trailers. Project also investigating the scale-up of the system to larger sizes up to 65 MW.
### Hydrogen Experience
**Owner's Engineering, Studies, Technical Oversight**

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<tr>
<td>Confidential</td>
<td>Confidential, U.S.</td>
<td>Combined Cycle and Simple Cycle</td>
<td>GE, LM6000</td>
<td>Q4 2019–Q1 2020 (4 months)</td>
</tr>
</tbody>
</table>

**Multiphase study to evaluate hydrogen cofiring as compared to traditional carbon capture at two separate facilities (one combined cycle and one simple cycle)**

Conducted study to determine the technical and economic feasibility of carbon reduction strategies after evaluating both hydrogen cofiring and traditional carbon capture. The initial study phase for hydrogen cofiring evaluated hydrogen generation technologies and storage methods (study also considered carbon capture). Consideration was given to onsite generation and onsite storage of hydrogen. Preliminary selections for hydrogen generation technology and hydrogen storage methods were set in this phase, based on high-level cost and technical feasibility considerations. The subsequent study phase for hydrogen cofiring developed the technical impacts and cost implications of onsite generation of green hydrogen (via renewable-powered electrolysis), onsite storage of hydrogen, and cofiring of hydrogen up to a specified percentage (limited by the existing gas turbine technology).

| Confidential    | Confidential, U.S.     | Coal-Fired Power Plant              | Coal-Fired Boiler       | 2019–2020                 |

**Coal-to-gas repowering study for firing hydrogen-rich gas at ~120-MW coal power plant unit**

Conducted study that included conceptual engineering, permitting and environmental investigations, and a cost estimate. The hydrogen source in this case was via pipeline from a neighboring facility; therefore, the study included both offsite and onsite transmission pipeline fuel delivery system infrastructure, such as a gas metering and regulation (M&R) stations, gas compression technology, flare technology and more, as well as BOP supporting systems. Several compressor OEMs were engaged related to the supply of large, multistage hydrogen compressors needed to meet the required pressure and flow at the boiler. The study also interfaced with the boiler OEM related to modifications needed to convert from coal to the hydrogen-rich gas as the primary fuel source, with natural gas as a secondary fuel source.
Carbon Dioxide (CO₂) Capture Experience  
Testing, Studies, Implementations

<table>
<thead>
<tr>
<th>Client</th>
<th>Project</th>
<th>Scope Summary</th>
<th>Time Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confidential Client</td>
<td>Detailed Design for Oxy Combustion</td>
<td>S&amp;L provided detailed design for a 150MW oxy combustion system.</td>
<td>Pending</td>
</tr>
<tr>
<td>Battelle Memorial Institute</td>
<td>Nuclear Direct Air Capture with Carbon Storage (NuDACCS)</td>
<td>The project includes a FEED study that will evaluate the design, cost, and lifecycle aspects associated with a nuclear waste heat driven DAC installation. S&amp;L will provide balance of plant support, integration design at the existing nuclear facility, and cost estimating.</td>
<td>2022-ongoing</td>
</tr>
<tr>
<td>Calpine</td>
<td>Deer Park Energy Center NGCC Carbon Capture System FEED Study</td>
<td>The scope of the project is to complete a FEED study of a modular, commercial-scale, 5 million tonnes net CO2 per year, capturing 95% of CO2 emissions Calpine’s Deer Park NGCC facility using Shell’s CANSOLV capture technology. S&amp;L’s scope on the project is to provide balance of plant and integration engineering and design, technical investigations and studies, development of capital and O&amp;M costs, and permitting.</td>
<td>2022-ongoing</td>
</tr>
<tr>
<td>Cleco</td>
<td>Project Diamond Vault FEED Study</td>
<td>S&amp;L is the Owner’s Engineer for the Project Diamond Vault FEED Study, a carbon capture evaluation on a petcoke-fired circulating fluidized bed boiler. This project is a multi-phase study where S&amp;L is coordinating a feasibility study with two solvent-based capture technologies, providing BOP engineering and overall cost of capture.</td>
<td>2022-ongoing</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Screening Study for Cement Facilities</td>
<td>S&amp;L performed a carbon capture screening study which involved evaluation of the clients existing cement facilities, applicable carbon capture technologies and a summary of the most feasible capture technology option for the client.</td>
<td>2022-ongoing</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>FOA Application Support</td>
<td>S&amp;L is providing consulting services to support a DAC Hub FOA, scope includes review and guidance during the development of the FOA application.</td>
<td>2022-ongoing</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Feasibility Study</td>
<td>S&amp;L performed a carbon capture feasibility study for a coal facility.</td>
<td>2022-ongoing</td>
</tr>
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</table>
# Carbon Dioxide (CO₂) Capture Experience

Testing, Studies, Implementations

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<tr>
<td>Confidential Client</td>
<td>CO₂ Capture Feasibility Study at a Combined Cycle Facility</td>
<td>S&amp;L performed an initial feasibility review of amine-based carbon capture technology at a new natural gas facility. The study included an evaluation of the utility requirements, cost estimates, system economics, site arrangement drawings, and project schedule for equipment procurement and construction.</td>
<td>2022-ongoing</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Technology Screening and Feasibility Study</td>
<td>This project includes both a technology screening and site screening in preparation for a future CCUS project at one of the Owner’s existing cement facilities. This study will identify advantages, disadvantages, and major balance of plant considerations for each technology and facility. S&amp;L prepared a feasibility study based on the results of the initial screening effort to further evaluate the selected technology and site.</td>
<td>2022-ongoing</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Pilot Plant Design Support</td>
<td>S&amp;L provided engineering and design support for a CO₂ capture pilot plant’s infrastructure installation.</td>
<td>2022-ongoing</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Feasibility Study for NGCC Plant</td>
<td>S&amp;L performed a feasibility study for a natural gas combined cycle power plant using a solvent based carbon capture technology.</td>
<td>2022-ongoing</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Feasibility Study for Aluminum Plant</td>
<td>Feasibility study evaluating carbon capture technology applications on an aluminum production facility.</td>
<td>2022-ongoing</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Feasibility Study</td>
<td>S&amp;L performed a carbon capture feasibility study for a coke producer.</td>
<td>2022-ongoing</td>
</tr>
<tr>
<td>Global Thermostat</td>
<td>FEED Study</td>
<td>S&amp;L is leading design efforts for the direct air capture (DAC) island portion of a commercial-scale carbon capture, utilization, and DAC engineering study. S&amp;L’s scope is to perform a technoeconomic and life cycle analysis for the DAC island.</td>
<td>2022-ongoing</td>
</tr>
<tr>
<td>ION Clean Energy</td>
<td>FEED for a CO₂ Capture System at Calpine’s Delta Energy Center</td>
<td>The scope of the project is to complete a FEED Study for installing ION’s carbon capture system to be retrofitted onto Calpine’s Delta Energy Center (DEC), an existing 857-MW NGCC. S&amp;L’s scope on the project is to provide engineering and design for the entire project, technical investigations and studies, development of capital and O&amp;M costs, and permitting.</td>
<td>2022-ongoing</td>
</tr>
</tbody>
</table>
## Carbon Dioxide (CO₂) Capture Experience

**Testing, Studies, Implementations**

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<th>Client</th>
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<tbody>
<tr>
<td>Minnkota</td>
<td>Owner’s Engineer for Project Tundra FEED Study</td>
<td>S&amp;L provided Owner’s Engineering Support on the execution of an ongoing FEED study at a coal-fired power plant.</td>
<td>2022-ongoing</td>
</tr>
<tr>
<td>Minnkota</td>
<td>CO2 Pipeline Study</td>
<td>Study evaluating CO₂ off-take pipeline to support the ongoing Project Tundra FEED Study.</td>
<td>2022-ongoing</td>
</tr>
<tr>
<td>Sustainable Energy Solutions / Chart</td>
<td>Cryogenic Carbon Capture™ from Cement Production</td>
<td>The scope of the project is to design, build, commission and operate an engineering-scale CCC process at the Eagle Materials/Central Plains Cement Sugar Creek facility. S&amp;L’s scope on the project is to provide integration engineering, procurement support, as well as construction oversight and management.</td>
<td>2022-ongoing</td>
</tr>
<tr>
<td>University of Illinois at Urbana-Champaign</td>
<td>FEED Study of DAC and Utilization Technologies at U.S. Steel Facility</td>
<td>The project includes a FEED study that will evaluate the design, cost, and lifecycle aspects associated with a DAC installation using waste heat from an existing steel facility. S&amp;L will provide balance of plant cost estimating.</td>
<td>2022-ongoing</td>
</tr>
<tr>
<td>Basin Electric / Dakota Gasification</td>
<td>CO₂ Pipeline Detailed Engineering and Design</td>
<td>Detailed engineering and design for a high pressure (supercritical) CO₂ pipeline. The pipeline that will carry captured carbon dioxide from the Great Plains Synfuels Plant to a permanent geologic storage reservoir several miles away. Construction began in October 2021.</td>
<td>2021-ongoing</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>MENA Region</td>
<td>This study includes an evaluation of an oil and gas production facility to identify the sources of CO₂ emissions to determine which ones are viable candidates for capture. Viable CO₂ capture candidates are further vetted to identify the proper technology and produce a capital and operating costs. Impacts to the existing facility are also considered, such as materials of construction and availability of process cooling.</td>
<td>2021-ongoing</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>CO₂ Capture Feasibility Study for Cement Facilities</td>
<td>This project included an initial feasibility study to determine the cost and viability of installing a CO₂ capture system and evaluated several integrated and post-combustion capture technologies available commercially. Our scope includes technology screening and high-level cost evaluation for multiple facilities.</td>
<td>2021-ongoing</td>
</tr>
<tr>
<td>Client</td>
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<td>Scope Summary</td>
<td>Time Frame</td>
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<tr>
<td>Confidential Client</td>
<td>Compressor Expansion Study</td>
<td>S&amp;L is performing an evaluation of an existing compressor station and is performing a study to expand the compressor station to accommodate additional CO2 flow.</td>
<td>2021-ongoing</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>CO₂ Capture Feasibility Study at a Combined Cycle Facility</td>
<td>S&amp;L performed an initial feasibility review of amine-based carbon capture technology at a new natural gas facility. The study included an evaluation of the utility requirements, cost estimates, system economics, site arrangement drawings, and project schedule for equipment procurement and construction. The project also includes ongoing OE support for Pre-FEED work.</td>
<td>2021-ongoing</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>CO₂ Capture Feasibility Study at a Combined Cycle Facility</td>
<td>S&amp;L performed an initial feasibility review of amine-based carbon capture technology at a new natural gas facility. The study included an evaluation of the utility requirements, cost estimates, system economics, site arrangement drawings, and project schedule for equipment procurement and construction. This project includes ongoing support of permitting and site certification.</td>
<td>2021-ongoing</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>CO₂ Capture Feasibility Study at a Combined Cycle Facility</td>
<td>This project includes a techno-economic assessment to determine the cost and viability of installing and operating an amine-solvent-based CO₂ capture system on a natural gas combined-cycle facility.</td>
<td>2021-ongoing</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>CO₂ Capture Feasibility Study for Cement Facilities</td>
<td>This project includes an initial feasibility study to determine the cost and viability of installing an amine-based CO₂ capture system at an existing facility. S&amp;L scope includes site-selection, conceptual design, and high-level cost evaluation for the selected facility.</td>
<td>2021-ongoing</td>
</tr>
<tr>
<td>Membrane Technology Research (MTR)</td>
<td>Large Pilot Phase 3</td>
<td>This DOE-funded project, is an extension of an earlier phased project to complete a FEED study for MTR’s large-scale pilot skid. This phase involves the fabrication, installation, and operation of the pilot skid.</td>
<td>2021-ongoing</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>CO₂ Capture FEED Study at a Combined Cycle Facility</td>
<td>Owner’s Engineer support on a FEED study for full-scale capture at a natural gas combined cycle facility. Our scope includes process and BOP design review as well as input to technical investigations, integration, and costing. Additional scope includes contract development and permitting support.</td>
<td>2020-ongoing</td>
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</table>
## Carbon Dioxide (CO₂) Capture Experience
### Testing, Studies, Implementations

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<tr>
<th>Client</th>
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<tbody>
<tr>
<td>Global Thermostat</td>
<td>Direct Air Capture Pilot System</td>
<td>Engineering oversight and design support for Direct Air Capture Pilot System.</td>
<td>2020-ongoing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Detailed integration engineering and design of a 10 ton CO₂/day pilot skid at Calpine’s Los Medanos Energy Center Combined Cycle Facility. S&amp;L is supporting the review of the pilot skid design and performing all BOP engineering to integrate the pilot skid in with the host site. Phase 1 completed in July 2021, Phase 2 began in September 2021.</td>
<td>2020-ongoing</td>
</tr>
<tr>
<td>ION Clean Energy</td>
<td>CO₂ Capture Pilot Skid Design and Integration</td>
<td>S&amp;L performed a due diligence review on the operation of an amine-based carbon capture facility. This review included a risk analysis of technical and economic considerations for the facility.</td>
<td>2022</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Due Diligence Review</td>
<td>This project includes both a technology screening and site screening in preparation for a future CCUS project at one of the Owner’s existing lime facilities. This study will identify advantages, disadvantages, and major balance of plant considerations for each technology and facility.</td>
<td>2022</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Due Diligence Review of Novel Technology</td>
<td>S&amp;L performed a due diligence review of a new novel technology.</td>
<td>2022</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Technology and Host Site Screening</td>
<td>S&amp;L performed a feasibility study for a coal-fired power plant using a solvent based carbon capture technology. This project included the development of a FOA application for a feasibility study for co-firing biomass.</td>
<td>2022</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Feasibility Study for Coal Plant and FOA Application Support</td>
<td>This project includes both a technology screening and site screening in preparation for a future CCUS project at one of the Owner’s existing lime facilities. This study will identify advantages, disadvantages, and major balance of plant considerations for each technology and facility.</td>
<td>2022</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Pre-Feasibility Screening</td>
<td>S&amp;L performed a pre-feasibility screening of several combined cycle facilities to evaluate the potential impacts of retrofitting CO₂ capture.</td>
<td>2022</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Biomass Pre- FEED Study</td>
<td>Pre-FEED study evaluating carbon capture on an existing biomass power plant. Includes upfront technology evaluation, utility and cost development.</td>
<td>2022</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Feasibility Study for Natural Gas Processing Facility</td>
<td>S&amp;L performed a feasibility study for a new co-gen facility using a solvent based carbon capture technology to be installed at an existing natural gas process facility.</td>
<td>2022</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Feasibility Study</td>
<td>S&amp;L is performing a feasibility review of carbon capture technology on two existing coal-fired boilers.</td>
<td>2022</td>
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# Carbon Dioxide (CO₂) Capture Experience

## Testing, Studies, Implementations

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<tr>
<td>Confidential Client</td>
<td>FOA Application Support</td>
<td>S&amp;L performed a techno-economic analysis and supported the client with development of funding application documents for a potential future DOE funding opportunity.</td>
<td>2022</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Pre-Feasibility Study for Aluminum Plant</td>
<td>Pre-Feasibility study evaluating carbon capture technology applications on an aluminum production facility.</td>
<td>2022</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>FEED Study for NGCC Power Plant</td>
<td>S&amp;L completed a FEED Study for an existing NGCC plant. The scope included design of the process island and balance of plant systems, and resulted in an AACE Class 3 Cost Estimate and detailed execution schedule.</td>
<td>2022</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Due Diligence</td>
<td>S&amp;L performed a due diligence review of an ongoing CO2 capture project to support an investment decision in the project.</td>
<td>2022</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>FOA Application Support</td>
<td>This project includes a techno-economic assessment to determine the cost and viability of installing and operating an amine-solvent-based CO₂ capture system on a natural gas combined-cycle facility.</td>
<td>2022</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>FOA Application Support</td>
<td>S&amp;L provided application support for the DOE CarbonSAFE FOA (sequestration). This includes preparing application documents and developing preliminary design information.</td>
<td>2022</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Feasibility Study for Coal Plant</td>
<td>S&amp;L performed a feasibility study for a coal-fired power plant using a solvent based carbon capture technology.</td>
<td>2022</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Pathway to Decarbonized Power Sector by 2035</td>
<td>The current administration has set a goal for the US power sector to reach 100 percent carbon pollution-free electricity by 2035. This study provides an overview of the current power sector and the changes which could be implemented to support the goal of a decarbonized power sector by 2035.</td>
<td>2021-2022</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Pre-Feasibility Site and Technology Screening for Cement CCUS Project</td>
<td>This project includes both a technology screening and site screening in preparation for a future CCUS project at one of the Owner's existing cement facilities. This study will identify advantages, disadvantages, and major balance of plant considerations for each technology and facility.</td>
<td>2021-2022</td>
</tr>
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<tr>
<td>Confidential Client</td>
<td>CO₂ Capture Feasibility Study at a LNG Facility</td>
<td>This project includes a feasibility study for installing and operating a CO₂ capture system on a liquified natural gas (LNG) facility. As part of this project, a conceptual design and cost estimate will be developed. This project also includes an evaluation of potential off-take options, including sequestration and enhanced oil recovery.</td>
<td>2021-2022</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>CO₂ Capture Feasibility Study at a Combined Cycle Facility and FOA Application</td>
<td>This project includes a feasibility study for installing and operating an amine-solvent-based CO₂ capture system on a natural gas combined-cycle facility. This project includes a screening of potential facilities, and evaluation and selection of a technology vendor to support future phases. Finally, this project also included the development of a FOA Application for a FEED Study.</td>
<td>2021-2022</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Confidential</td>
<td>S&amp;L is performing a technical and economic assessment of a CO₂ capture facility based on the use of the client's proprietary solvent as part of a DOE-funded project.</td>
<td>2021-2022</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Cement Facility Test Center Conceptual Design</td>
<td>Sargent &amp; Lundy is providing conceptual engineering and preliminary costs for developing an on-site test center which will supply a slip stream of flue gas from a cement facility to an area that has been developed for future testing of CO₂ capture technologies.</td>
<td>2021-2022</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Conceptual Study for Synthetic Gas Production</td>
<td>Study to develop a method to simulate flue gas from a natural gas combustion turbine at an existing coal-fired facility for use with pilot CO₂ capture technologies.</td>
<td>2021-2022</td>
</tr>
<tr>
<td>Global Thermostat</td>
<td>Electrical Design Work</td>
<td>S&amp;L performed electrical design work for Global Thermostat's DAC Pilot Project.</td>
<td>2021-2022</td>
</tr>
<tr>
<td>MidAmerican Energy</td>
<td>CO₂ Capture FEED Study Technology Selection</td>
<td>Owner's Engineer support to develop a FEED study for full-scale capture at a coal-fired power plant. S&amp;L scope includes development of an RFP document and support to evaluate a select a technology supplier and team to complete the FEED study.</td>
<td>2021-2022</td>
</tr>
<tr>
<td>Minnkota</td>
<td>Project Tundra FEED Study Support</td>
<td>S&amp;L is performing a steam extracting study as part of the ongoing Project Tundra effort, a CO₂ capture FEED Study.</td>
<td>2021-2022</td>
</tr>
<tr>
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<tr>
<td>Enchant Energy</td>
<td>San Juan CO₂ Capture FEED Study</td>
<td>This DOE-funded project includes a FEED study for a large-scale installation of amine-based CO₂ capture technology at the San Juan Generating Station (SJGS). Our scope includes design of the balance-of-plant (BOP) scope and interconnections to support the capture facility, technical investigations and studies, technical specifications for equipment, development of capital and O&amp;M costs, and regulatory reviews.</td>
<td>2020-2022</td>
</tr>
<tr>
<td>Enchant Energy / New Mexico Tech</td>
<td>Enchant SJGC Carbon SAFE</td>
<td>As part of the New Mexico Tech and Enchant DOE funded Carbon SAFE project, S&amp;L is providing input to sequestration well permitting. This includes Class VI permitting support for the sequestration wells and NEPA support. As part of continued efforts of the Enchant CO₂ capture study, Sargent &amp; Lundy will be performing a technical review of the downstream supercritical CO₂ pipeline to transfer CO₂ to the pipeline corridor and sequestration locations.</td>
<td>2020-2022</td>
</tr>
<tr>
<td>Membrane Technology Research (MTR)</td>
<td>CO₂ Capture Pre-FEED at a Cement Facility</td>
<td>Project management and engineering development of a CO₂ Pre-FEED for the Balcones cement kiln. Sargent &amp; Lundy’s role includes performing studies, balance-of-plant engineering and design, constructability review, and cost estimating.</td>
<td>2020-2022</td>
</tr>
<tr>
<td>Membrane Technology Research (MTR)</td>
<td>CO₂ Capture FEED Study</td>
<td>This DOE-funded project includes a FEED study for a full-scale installation of MTR’s CO₂ capture membrane technology. Our scope includes design of the balance-of-plant (BOP) scope and interconnections to support the capture facility, technical investigations and studies, technical specifications for equipment, development of capital and O&amp;M costs, and regulatory reviews.</td>
<td>2020-2022</td>
</tr>
<tr>
<td>Cleco</td>
<td>CO₂ Capture Feasibility Study at a Coal-fired Facility</td>
<td>This project includes an initial feasibility study to determine the cost and viability of installing a CO₂ captures system and will evaluate solvent-based technology suppliers.</td>
<td>2021</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Funding Application Support</td>
<td>Development of funding application documents for a potential future DOE funding opportunity. Additional activities requested by the client as a follow-up to a pre-feasibility study performed by S&amp;L for a cement facility.</td>
<td>2021</td>
</tr>
</tbody>
</table>
## Carbon Dioxide (CO₂) Capture Experience

Testing, Studies, Implementations

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<tr>
<td>Confidential Client</td>
<td>CO₂ Capture Feasibility Study for Cement Facilities</td>
<td>This project includes an initial feasibility study to determine the cost of installing several integrated and post-combustion CO₂ capture technologies at two facilities. Our scope includes site evaluation/selection and technology screening to pursue a more detailed second phase study.</td>
<td>2021</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>SMR CO₂ Capture Cost Estimate</td>
<td>This project included the development of a high-level capital and operating cost associated with retrofitting an existing steam methane reformer (SMR) with amine-based capture technology.</td>
<td>2021</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>CO₂ Capture Technology Screening Study</td>
<td>This project includes a techno-economic assessment to determine the cost and viability of installing and operating an amine-solvent-based CO₂ capture system on a natural gas combined-cycle facility.</td>
<td>2021</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Pre-Feasibility Site Screening for CCUS Projects</td>
<td>This project includes the review and evaluation of a utility’s fleet, to evaluate feasibility of applying CCUS at each specific facility. This study will identify advantages, disadvantages, and major balance of plant considerations for each facility.</td>
<td>2021</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Project / Technology Readiness Evaluation White Paper</td>
<td>This white paper discusses the various levels of technology development, including the goals associated with each phase, as well as the challenges and factors that have led to success for technologies and projects.</td>
<td>2021</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Green Cement and Concrete</td>
<td>This study provides an overview of the current cement and concrete market, which is one of the largest producers of CO₂ globally. This study identified the potential methods for reducing GHG emissions throughout the production of concrete – carbon capture at cement production facilities, use of alternate aggregate materials, or use of CO₂ during concrete production and curing.</td>
<td>2021</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Owner’s Engineer Review of FEED Study</td>
<td>S&amp;L is reviewing the final deliverables from a FEED study completed for applying amine-based CO₂ capture equipment to a liquified natural gas (LNG) facility. The results of this review will be summarized in a memo with recommendations to be considered by the Owner for the implementation phase of the project.</td>
<td>2021</td>
</tr>
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# Carbon Dioxide (CO₂) Capture Experience

## Testing, Studies, Implementations

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<tr>
<td>Confidential Client</td>
<td>CO₂ Capture Feasibility Study for Cement Facilities</td>
<td>This project includes an initial feasibility study to determine the cost and viability of installing a CO₂ capture system and evaluated several post-combustion capture technologies available commercially. Our scope includes site-selection, technology screening and high-level cost evaluation for multiple facilities.</td>
<td>2021</td>
</tr>
<tr>
<td>Global Thermostat</td>
<td>HAZOP Study</td>
<td>S&amp;L facilitated a HAZOP for Global Thermostat’s DAC System.</td>
<td>2021</td>
</tr>
<tr>
<td>Jupiter Oxygen Corporation</td>
<td>Oxy-Combustion and CO₂ Capture FEED Study</td>
<td>Sargent &amp; Lundy is supporting a FEED study for the conversion of an existing coal-fired power plant to oxy-combustion, in conjunction with installing a CO₂ capture system. Our scope includes coordination of the various contractors, and design of the balance-of-plant (BOP) scope and interconnections to support the conversion and modification, technical specifications for equipment, development of capital and O&amp;M costs, and regulatory reviews.</td>
<td>2020-2021</td>
</tr>
<tr>
<td>MidAmerican Energy</td>
<td>Louisa Generating Station Unit 1 Preliminary Conceptual Design Study</td>
<td>S&amp;L conducted a preliminary conceptual design study for a CO₂ capture installation retrofit. The study scope includes development of preliminary conceptual layouts, utility estimates, high-level capital and O&amp;M cost estimates, and economic analysis.</td>
<td>2020-2021</td>
</tr>
<tr>
<td>Prairie State Generating Station</td>
<td>CO₂ Capture FEED Study</td>
<td>This DOE-funded project includes a FEED study for a large-scale installation of MHI’s CO₂ technology at the Prairie State facility. Our scope includes detailed design of the host site integration including ductwork design and all project permitting.</td>
<td>2020-2021</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>CO₂ Capture Feasibility Study at a Combined Cycle Facility</td>
<td>This project included an initial technology review of several carbon reduction options including cost and technical evaluations. As a result of the initial review, a techno-economic assessment was performed to determine the cost and viability of installing and operating an amine-solvent-based CO₂ capture system on a natural gas combined-cycle facility.</td>
<td>2019-2021</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Techno-Economic Assessment</td>
<td>S&amp;L developed a techno-economic assessment for several natural gas combined cycle facilities.</td>
<td>2019-2021</td>
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<tr>
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<tr>
<td>ION Clean Energy</td>
<td>CO₂ Capture FEED Study</td>
<td>This DOE-funded project includes a FEED study for a large-scale installation of ION’s CO₂ technology at the GGS facility. This is a continuation of a previous pre-FEED project. Our scope includes detailed design of the BOP scope and interconnections to support the capture facility, technical investigations and studies, technical specification for BOP equipment, development of capital and O&amp;M costs, and permitting.</td>
<td>2019-2021</td>
</tr>
<tr>
<td>Membrane Technology Research (MTR)</td>
<td>Large Pilot Phase 2 Study (FEED)</td>
<td>This DOE-funded project, which kicked off in September 2019, includes a FEED study for a large-scale pilot of MTR’s CO₂ capture membrane technology. S&amp;L’s scope includes design of the BOP scope and interconnections to support the pilot unit, technical specification for BOP equipment, development of capital and O&amp;M costs, and permitting.</td>
<td>2019-2021</td>
</tr>
<tr>
<td>Southwest Research Institute (SwRI)/DOE</td>
<td>Large Pilot Phase 2 Study (FEED)</td>
<td>This DOE-funded project kicked off in October 2019 and includes a FEED study for a large-scale pilot for International Test and Evaluation Association’s (iTEA) flameless pressurized oxy-combustion technology. This is a continuation of the previous Phase 1 project, and our scope includes design of the BOP scope and interconnections to support the pilot unit, as well as development of capital and O&amp;M costs.</td>
<td>2019-2021</td>
</tr>
<tr>
<td>MidAmerican Energy</td>
<td>Preliminary Conceptual Design Study – Tech Screening Study</td>
<td>As part of continued efforts for CCS integration at WSEC, we are conducting a technology screening and vendor solicitation. The scope includes reviewing vendor information to determine the optimal selection for the implementation of the project.</td>
<td>2020</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Confidential / Scalability Study</td>
<td>This study includes the evaluation of a pilot skid installation, and the identification of requirements to scale up the system and develop a conceptual “full-scale” system including an estimated construction schedule, conceptual design, capital cost estimate, and O&amp;M cost estimate.</td>
<td>2019-2020</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Cryogenic Carbon Scalability Study</td>
<td>S&amp;L developed a scalability study for a cryogenic carbon capture system.</td>
<td>2019-2020</td>
</tr>
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<tr>
<td>MidAmerican Energy</td>
<td>Preliminary Conceptual Design Study</td>
<td>Sargent &amp; Lundy developed a preliminary conceptual design study for a CO2 capture retrofit. The scope of the study includes develop of preliminary conceptual layouts, utility estimates, high level capital and O&amp;M costs, and a preliminary economic analysis.</td>
<td>2019-2020</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Pre-Feasibility Screening</td>
<td>S&amp;L performed preliminary screening and investigations of potential CO2 capture technologies and host facilities.</td>
<td>2019</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Confidential / Preliminary Feasibility and Cost Study</td>
<td>Study the applicability of 40,000 tonnes/year slipstream CO2 capture for water treatment at new international S.C. boiler. Scope includes preliminary integration design, arrangement, and cost estimating.</td>
<td>2019</td>
</tr>
<tr>
<td>Enchant Energy</td>
<td>SJGS Pre-Feasibility Study</td>
<td>Evaluated high level feasibility and costs of integrating CO2 capture technologies at SJGS for use in EOR. As part of this study, S&amp;L defined the balance-of-plant scope for the station with consideration for existing available infrastructure.</td>
<td>2019</td>
</tr>
<tr>
<td>Southwest Research Institute</td>
<td>Large Pilot Phase 1 Study (pre-FEED)</td>
<td>The project is a pre-FEED study for a large sale pilot for ITEA’s flameless pressurized oxy-combustion technology. As part of the work, S&amp;L reviewed the process equipment design and developed the BOP scope and interconnections to support the pilot unit; including supply of coal, oxygen, water, electricity and waste disposal. S&amp;L also developed preliminary drawings, and capital and O&amp;M costs for the pilot facility; as well as the Environmental Information Volume (EIV) for the NEPA process.</td>
<td>2019</td>
</tr>
<tr>
<td>Carbon Capture Machine (UK) Limited</td>
<td>X-Prize Carbon Capture Competition / Test Skid Design</td>
<td>As subcontractor to CCM, Sargent &amp; Lundy was supporting the design of pilot skid carbon capture system to be installed at the Wyoming ITC as part of X-Prize’s Carbon Capture Competition. Sargent &amp; Lundy’s role on the project included equipment design oversight. The project was suspended before it was completed.</td>
<td>2018-2019</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Confidential / Test Skid Design</td>
<td>Owner’s Engineering for design of test skid for new carbon capture technology. The skid will be installed at various industrial applications.</td>
<td>2018-2019</td>
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## Carbon Dioxide (CO₂) Capture Experience

**Testing, Studies, Implementations**

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<tr>
<td>ION Clean Energy</td>
<td>Carbon Capture, Design &amp; Costing Study</td>
<td>As a subcontractor to ION, Sargent &amp; Lundy supported the development of a commercial carbon capture design and costing study for a 300-MW (equivalent) carbon capture system. Sargent &amp; Lundy’s role includes performing studies, balance-of-plant engineering and design, constructability review, and cost estimating.</td>
<td>2018-2019</td>
</tr>
<tr>
<td>Jupiter Oxygen Corporation</td>
<td>Oxy-Combustion and CO₂ Capture Feasibility Study</td>
<td>Sargent &amp; Lundy participated in a feasibility study to evaluate conversion of an existing coal-fired unit to oxy-combustion, in conjunction with installing a CO₂ capture system. This includes coordinating efforts of multiple subcontractors, as well as performing BOP engineering and cost estimating.</td>
<td>2018-2019</td>
</tr>
<tr>
<td>Basin Electric Power Cooperative</td>
<td>Integrated Test Center (ITC) Design</td>
<td>Sargent &amp; Lundy provided engineering and developed costs to support development of ITC using 20-MWe (87,500-ACFM) slip stream of flue gas from Dry Fork Station, divided amongst six test sites, as well as overseeing construction. The first scheduled tests ITC evaluated six different CO₂ capture technologies for X-Prize’s Carbon Capture Competition to demonstrate beneficial utilization of the recovered CO₂.</td>
<td>2015-2018</td>
</tr>
<tr>
<td>University of Utah</td>
<td>CCS Study</td>
<td>Assisting client in evaluating feasibility and economics of integrating CO₂ capture technologies at existing plant for sequestration in nearby geological sites. Evaluation included comparison of traditional amine-based technology and emerging cryogenic technology. As part of this project, S&amp;L defined the balance-of-plant impacts and estimated the associated costs for the station for each technology.</td>
<td>2017</td>
</tr>
<tr>
<td>University of Wyoming</td>
<td>CCS Study</td>
<td>High-level evaluation of station as a potential candidate for CO₂ capture technology to provide a concentrated CO₂ stream for sequestration. Evaluation was conducted as part of the DOE-funded CarbonSAFE project.</td>
<td>2017</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Confidential / Economic Evaluation of Carbon Capture for EOR</td>
<td>Evaluated feasibility and economics of integrating CO₂ capture technologies at existing plant for use in EOR at nearby oil fields. As part of this project, S&amp;L defined the balance-of-plant impacts and estimated the associated costs for the station.</td>
<td>2016-2017</td>
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</table>
## Carbon Dioxide (CO₂) Capture Experience

Testing, Studies, Implementations

<table>
<thead>
<tr>
<th>Client</th>
<th>Project</th>
<th>Scope Summary</th>
<th>Time Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>CARBON 360/Petra</td>
<td>CCUS Implementation</td>
<td>Primary scope: (1) Owner's Engineer during development and design phase of project. Included design reviews and HAZOP participation in addition to detailed drawing review; (2) Detailed design of plant interconnection for 240 MWe to the host unit (Unit 8) and the carbon capture island.</td>
<td>2013-2017</td>
</tr>
<tr>
<td>Confidential Client</td>
<td>Confidential / Economic Evaluation of Carbon Capture for EOR</td>
<td>Assisted client in evaluating feasibility of installing a CO₂ capture system at existing plant for use in EOR at nearby oil fields. This project included an evaluation of the permitting requirements for both the onsite capture equipment and the associated CO₂ pipeline. Subsequent to the permitting evaluation, S&amp;L evaluated the technical feasibility of integrating various configurations of CO₂ capture technology within the limitations of the existing station.</td>
<td>2016</td>
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<tr>
<td>Confidential Client</td>
<td>Confidential / Novel CO₂ Solvent Technical and Economic Assessment</td>
<td>A developer of a second-generation CO₂ capture solvent contracted S&amp;L to perform a technical and economic assessment of a CO₂ capture facility based on the use of their proprietary solvent as part of a DOE-funded project. Assessment evaluated the incremental cost of CO₂ capture using this solvent based on installation at a theoretical greenfield power plant. Included development of conceptual design for the base plant and capital and O&amp;M costs for the entire facility, including the CO₂ capture island.</td>
<td>2015-2016</td>
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<tr>
<td>Confidential Client</td>
<td>Confidential / Novel CO₂ Capture Technology Evaluation</td>
<td>A major U.S. utility company contracted Sargent &amp; Lundy to perform a FEED study, in conjunction with the technology developer, to determine how to integrate the technology into an existing power plant; provide preliminary design information, identify risks and unknowns; and to conduct capital and O&amp;M cost estimates to help the client evaluate the economics of developing the project further. The system was designed to capture 100,000 tons per year of CO₂, roughly equivalent to a 15-MWe slipstream of flue gas.</td>
<td>2014-2015</td>
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<tr>
<td>U.S. DOE</td>
<td>Gasification Projects</td>
<td>Perform due diligence analyses on the projects for the U.S. DOE Loan Guarantee Program. Projects intended to produce substitute natural gas (SNG) from coal and petroleum coke to power two plants ranging in size from 300 to 400 MW. Sale of CO₂ is beneficial to use in enhanced oil recovery (EOR) applications.</td>
<td>2010-2014</td>
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<td>Client</td>
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<tr>
<td>NRG Energy</td>
<td>CCUS FEED Study</td>
<td>A previous Unit 7 study evolved to Unit 8 and was expanded in size to a 240 MWe slipstream. Project received a funding grant from the U.S. DOE. S&amp;L was heavily involved in the development of the proposal to the DOE. As owner’s engineer, S&amp;L reviewed all technical aspects of the project, including HAZOP reviews for the facility.</td>
<td>2010-2013</td>
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<tr>
<td>U.S. DOE</td>
<td>Efficiency Study</td>
<td>Develop conceptual design for a new 500 MW PC power plant equipped with CO₂ recovery that is fully thermally integrated. Determined overall efficiency improvements that are possible due to integration and compared these to existing concepts.</td>
<td>2009-2013</td>
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<tr>
<td>Confidential Client</td>
<td>Repowering / CCS</td>
<td>Compared costs for repowering several existing steam turbines totaling approximately 500 MW with natural gas combined-cycle power systems with installations of retrofit carbon capture system technologies on existing boilers.</td>
<td>2010</td>
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<tr>
<td>NRG Energy</td>
<td>CCUS DOE Proposal</td>
<td>Supported proposal development to DOE for Clean Coal Power Initiative (CCPI) 3 for 60 MWe slipstream (161,700-SCFM) demonstration facility on Unit 7. Facility would remove SO₂ and capture 1,194 tons per day of CO₂ using Fluor Econamine Plus and wet limestone scrubbing technology. The captured CO₂ would be used for EOR in nearby oil fields. As owner’s engineer, S&amp;L provided all BOP engineering, including compression.</td>
<td>2008-2010</td>
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