JISEA Joint Institute for Strategic Energy Analysis

Pathways to Decarbonization: Natural Gas and Renewable Energy

Lessons Learned from Energy System Stakeholders

Jacquelyn Pless, Douglas J. Arent, Jeffrey Logan, Jaquelin Cochran, Owen Zinaman, and Camila Stark

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Technical Report
NREL/TP-6A50-63904
April 2015

Contract No. DE-AC36-08GO28308

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Prepared under Task No. WWJI.1022

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Foreword

Our Transforming Energy Economy: Pathways to a Decarbonized Future

Unconventional natural gas, and specifically shale gas, is reshaping the U.S. energy sector. Like renewable energy and nuclear energy, natural gas offers a potential pathway toward a decarbonized energy system. The Joint Institute for Strategic Energy Analysis examines all potential pathways to provide useful insight to policy and investment decision makers. This report, based on input from energy system stakeholders in workshops held around the country, focuses on potential synergies between natural gas and renewables.

In 2011, JISEA published its first major report in a series of studies on natural gas and the U.S. energy sector. Titled *Natural Gas and the Transformation of the U.S. Energy Sector: Electricity*, the report provides a new methodological approach to estimate natural gas related greenhouse gas emissions, tracks trends in regulatory and voluntary industry practices, and explores various electricity futures.

Since then, our work has examined additional critical topics related to the role of natural gas in our energy economy, including potential synergies between natural gas and renewable energy in the power and transportation sectors; and the state of knowledge about emissions of natural gas systems compared to other fuel sources. Our ongoing work in this space will explore economic, environmental, and systems impacts of natural gas development and use.

As the natural gas landscape continues to shift in the United States and globally, JISEA believes that bringing objective views and analytical expertise to bear on issues critical to our energy system transformation can help move discussion forward on a productive path. It is part of our mission to provide leading-edge, objective, high-impact research and analysis to inform global energy investment and policy decisions. This report is part of our growing portfolio of natural gas research and reflects our commitment to "getting gas right." We look forward to your feedback and thank you for your interest in our work.

Doug Arent

Executive Director, Joint Institute for Strategic Energy Analysis

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Acknowledgments

This paper was prepared with input and feedback from many experts. The authors would like to acknowledge Carl Linvill of the Regulatory Assistance Project for reviewing and commenting on a draft of this paper.

The authors would also like to acknowledge the numerous and substantial contributions made by participants of the *Synergies of Natural Gas and Renewable Energy: 360 Degrees of Opportunity* workshop series convened by the Joint Institute for Strategic Energy Analysis (JISEA) in collaboration with the Center for the New Energy Economy and the Gas Technology Institute in 2014. The authors would like to thank former Governor Bill Ritter, founder and director of the Center for the New Energy Economy at Colorado State University, and Edward Johnston, Vice President of Research Operations at the Gas Research Institute for co-hosting the workshop series. A full list of participants is provided in Appendix A.

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Executive Summary

Overview

Ensuring the resilience, reliability, flexibility, and affordability of the U.S. electric grid is increasingly important as the country addresses climate change and an aging infrastructure. State and federal policy and actions by industry, non-profits, and others create a dynamic framework for achieving these goals. Three principle low-carbon generation technologies have formed the basis for multiple scenarios leading toward a low-carbon, resilient, and affordable power system. While there is no "silver bullet," one avenue identified by key stakeholders is the opportunity to invest in natural gas (NG) and renewable resources, both of which offer abundant domestic resource bases and contribute to energy independence, carbon mitigation, and economic growth.

NG and renewable electricity (RE) have traditionally competed for market share in the power sector, but there is a growing experience base and awareness for their synergistic use (Cochran et al. 2014). Building upon these observations and previous work, the Joint Institute for Strategic Energy Analysis (JISEA), in collaboration with the Center for the New Energy Economy and the Gas Technology Institute, convened a series of workshops in 2014 to explore NG and RE synergies in the U.S. power sector. **This report captures key insights from the workshop series, *Synergies of Natural Gas and Renewable Energy: 360 Degrees of Opportunity***, as well as supporting economic valuation analyses conducted by JISEA researchers that quantify the value proposition of investing in NG and RE together as complements.

Key Stakeholder Insights From NG-RE Workshop Series

Throughout the workshop series, stakeholders identified several themes that characterize the current opportunities for and barriers to pursuing NG and RE synergies. Participants highlighted the opportunity to exploit large domestic resources offered by both NG and renewables, which offers energy security benefits and justifies both short- and longer-term strategic planning. Furthermore, increasing variable RE integration more generally necessitates flexible resources, such as generation from fast response NG turbines. **Together, NG and RE can help contribute to a low-carbon, resilient, and reliable electrical grid by diversifying the electricity mix and hedging risk associated with market and policy uncertainties.** Factors driving the transition toward synergistic portfolios of NG and RE include price stability, technological advances, policy incentives, regulatory changes, flattening demand, and innovative business models and financing mechanisms.

However, increasing NG-RE investments does not come without its challenges. In particular, harmonization between NG and electric power markets is necessary in order to maximize returns on investments and to improve operational coordination. Flexible contracting arrangements between sectors and the ability to manage schedule changes intra-hour could contribute to gas-electric market harmonization. Furthermore, infrastructure would be needed for both NG and RE expansion, and solutions such as joint transmission financing or co-located investment projects could provide further financial benefits.

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Lastly, stakeholders highlighted the importance of creating value for the end-use electricity customer and the mechanisms through which NG-RE synergies can achieve this objective. Customers increasingly desire more control and transparency in their energy use, and energy services providers are increasingly focused on customer-oriented solutions. Accordingly, **a key driver for NG and RE synergies will be the ability to operate systems in a way that creates value for the customer, such as by providing more reliable, resilient, and affordable service.** Solutions at both the project and system-wide levels can integrate NG and RE with continued cost and technology improvements.

At the same time, consumers are not merely passive recipients of NG-RE services but also producers. Consumer resources, including distributed generation from renewable resources and NG, energy efficiency, storage, and demand response contribute significant value to the power sector, and customers are at the center expressing preferences and exercising choice. The NG-RE services can compete for the consumer's dollar or compete to provide system services to the utility or system operators. In other words, in addition to generation resources, customer resources also provide value and system flexibility.

Main Findings From Quantitative Analyses

Although NG-RE synergies are anecdotally documented in the literature (see Lee et al. [2012] and Cochran et al. [2014]) and demonstrated across various existing case studies, less work to date quantifies the value proposition of investing in NG and RE synergies. Quantitative analysis conducted to inform the workshop series aimed to help close this gap by applying economic valuation techniques to hypothetical project-level investment opportunities as well as quantifying a system-wide case study.

At the distribution edge, standalone hybrid systems consisting of NG microturbines and solar photovoltaic (PV) systems in the states of New York and Texas were analyzed.[1] Key market characteristics considered include NG price volatility, electricity rate structure, and load profile at the hourly level. Depending on location and local market characteristics, hybrid systems often cost less and are more attractive investment opportunities than NG-only or RE-only systems, with all else equal.[2] Because the customer load shape is passive in our analysis, co-optimization of efficiency and load flexibility could contribute even more to a broader systems solution.

Evaluating possible long-term transition pathways to reduce carbon emissions up to 80% by 2050, analysis of scenarios from the *Renewable Electricity Futures* study (e.g., NREL 2012) indicate that, from a system-wide perspective, NG-RE synergies offer portfolio

[1] Note that these are only two specific examples of potential NG-RE synergies and do not fully incorporate a systems solution. For instance, a comprehensive systems solution might also consider customer consumption flexibility and efficiency, further enhancing the effectiveness of these solutions.

[2] These project analyses are conducted assuming a 25-year project lifetime for residential systems and a 30-year project lifetime for commercial systems. Economic attractiveness is largely driven by the end-user's load profile and the performance efficiency of the natural gas system component. When non-electric natural gas demand is higher, such as in regions with significant natural gas heating demands in the face of tumultuous winters, including NG in the distributed generation systems is more economically attractive.

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risk-reducing benefits. Near- and medium-term contributions from NG generators offer significant financial incentives for long-term asset finances as utilization rates decrease under a scenario that transitions the United States to high renewable electricity shares by 2050. Capacity-based revenue models and adaptive regulatory frameworks materially increase the long-term return to NG generators.

Moving Forward

The JISEA work stream on NG-RE synergies transpired from stakeholder discussions around investing in a more resilient, reliable, clean, and affordable electricity sector. The workshop series and quantification exercises built upon this insight and previous JISEA research in an effort to identify key opportunities for and barriers to NG-RE synergistic investments.

The findings of the workshop series indicated that continued exploration of the concept and solution space going forward would be valuable. For instance, analyses of real-life case studies are warranted to better understand the mechanisms required for generating the highest possible investment returns. Perhaps more importantly, quantifying the non-market benefits and costs, such as the value of flexible NG-fired generation as well as the value of reliability and resiliency, is necessary for more accurately capturing the true value NG-RE synergies. This is particularly relevant for certain industries where reliable power is a key differentiator for achieving financial goals and targets and there is little margin for error if power is interrupted. Lastly, exploring potential policy and regulatory schemes that could enable better gas-electric market coordination is needed to help mitigate market coordination barriers.

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Introduction

The North American shale revolution combined with global advances in renewable energy continues to alter the investment, policy, and regulatory landscapes. Although natural gas (NG) and renewables have traditionally competed for market share, particularly in the power sector, there is growing potential to use these technologies in a complementary fashion. NG and renewable electricity (RE) have the capability to deliver favorable energy outcomes given their abundant domestic resource bases, low-carbon footprint, and symbiotic risk profiles. Both resources in isolation might face disapproval on a variety of social, political, or even economic grounds, but their pairing offers economic, security, environmental, and financial benefits, as well as a long-term competitive advantage to industry.

Building upon these observations and previous work, the Joint Institute for Strategic Energy Analysis (JISEA), in collaboration with the Center for the New Energy Economy and the Gas Technology Institute, convened a series of workshops in 2014 to explore NG and RE synergies in the U.S. power sector. This report captures key insights from the workshop series, *Synergies of Natural Gas and Renewable Energy: 360 Degrees of Opportunity*. It also provides a summary of recent analyses conducted by JISEA researchers that quantifies the value of investing in NG and RE together at the project and system-wide levels.

The goal for each workshop in the series was to define unique regional or sectoral opportunities for NG and RE to complement one another and to define measurable action that could support the transformation of the electricity sector to one that is more resilient, reliable, affordable, and low carbon. Workshops were conducted under Chatham House Rules to encourage candid and meaningful dialogue. Participants included industry and policy thought leaders in NG and RE markets, representing a diverse sampling of stakeholders, including:

- Public utility commissions
- Independent systems operators
- Utilities and other generators
- Investors
- Policymakers
- Renewable energy developers
- NG developers
- Original equipment manufacturers
- National laboratories
- Consulting agencies
- Universities and research institutions.

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A sampling of questions were posed to participants to help guide conversations:

- What is the importance of NG and RE synergies, and where do they occur?
- What are example business cases for synergies, including investment and finance options? How can investors harvest value-added revenue streams by linking together NG and RE projects?
- What policy options can help catalyze this linkage?
- How can energy service providers position themselves for the current and coming changes resulting from increasing shares of NG and RE and other sweeping changes in today's energy sector?
- How can risk over policy uncertainty be mitigated?
- What might future analyses look like in this space to inform the dialogue on NG and RE synergies?

The dialogue in this report builds on previous work conducted by JISEA and its partner institutions that explore the system-level solutions, platforms for partnership, and new business models that NG and RE can offer (Lee et al. 2012; Cochran et al. 2014).

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Key Stakeholder Insights From NG-RE 360 Degrees of Opportunity Workshop Series

Several recurring themes surfaced throughout the workshops that characterize the current opportunities and future business models for pursuing NG and RE synergies. This section synthesizes key messages from the participants. This synthesis captures only the widely agreed upon points of emphasis in the discussion rather than a comprehensive account of the dialogue. The synthesis also does not represent a consensus among all participating parties or any individual opinions as there are differing vested interests, as expected.

The identified themes include:

- Opportunities for and benefits of NG-RE synergies
- Barriers to NG-RE synergies
- Importance of flexibility and diversification for enhancing resiliency
- Infrastructure investment needs
- Innovative business models
- Energy services provider of the future and creating value for and procuring value from the customer
- Importance of electric and gas coordination for NG-RE integration
- Importance of regulation and wider policy objectives
- Economically favorable hybrid systems.

Opportunities for and Benefits of NG-RE Synergies

- ***The United States has a large domestic resource base for both NG and renewable energy,*** justifying both short- and longer-term strategic planning. Used together or separately, these two energy sources can help address economic, security, and environmental concerns, and enhance a company's competitive advantage, but new challenges can also emerge as they become more widely used.
- ***Energy investments are undergoing substantial shifts in favor of NG and renewables.*** New capacity additions in the U.S. power sector today are increasingly dominated by NG and renewables. Since 2008, for example, NG and renewables have each accounted for nearly half of all new capacity additions, on average (BNEF 2015). Factors driving this power sector transition in the United States include: technological advances in hydraulic fracturing and renewables, technological advances in information communications and power system controls, policy incentives, regulatory changes (emission limits), flattening demand, and innovative financing mechanisms.
- ***Financing options are expanding, and some models offer opportunities that build on NG and RE synergies.*** Larger-scale investments are generally financed through power purchase agreement structures, capital markets, banks, or self-financing (from a state budget allocation or retained earnings). Smaller-scale

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investments can be financed through consumer loans, energy savings performance contracts, self-financing, energy service agreements, utility on-bill financing, mortgage-backed financing, public loan programs, utility incentive programs, and more. As synergies between NG and RE are found to exist at multiple levels—from hybrid systems to investment portfolios that reduce risk through asset diversification—financing models offer opportunities that build on NG and RE synergies. For instance, collocated assets could be securitized or financed together, or independent investments in NG and RE could be pooled and securitized to reduce systematic portfolio risks (Cochran et al. 2014) and benefit from installation economies of scale to drive down total costs.

- ***There exists a growing need for flexibility, resiliency, and reliability*** in many regions of the country given aging infrastructure, increasing impacts of storms and other natural disasters, and the lack of harmonization between NG and electric power markets. NG and RE attributes often align for effective system operations and can exhibit complementary risk profiles. Many gas generators are flexible and have quick ramping capabilities to support variable renewable generation. While NG prices continue to exhibit volatility—albeit at much lower price ranges than in the past—renewables can hedge fuel price risk because they have zero fuel costs. As the deployment of variable renewable generators increases, rapidly ramping NG is one option among many to ensure load is met reliably and affordably. Gas also can be stored or hedged to mitigate price risk.
- ***Moving toward a low-carbon future.*** Federal and state policies to limit carbon mitigation are advancing in some sectors, and although some consider the policies to be progressing slowly, many companies have already begun to internalize carbon costs and risks into their balance sheets. Both NG and RE can offer carbon-reduction benefits relative to the status quo.

Barriers to NG-RE Synergies

- ***Whether NG-RE synergies are economically, technically, and politically feasible still depends on many uncertain factors.*** Some market components that determine whether NG-RE synergies are feasible that remain uncertain include NG prices and contracting structures, the cost profile of renewables, state and federal policies, capacity markets, ancillary services markets, public concern about hydraulic fracturing and the so-called "license to operate", and future growth in electricity demand. Such uncertainties make it difficult to adequately project cost and revenue streams and introduce a source of risk. For instance, ancillary services are often critical for making certain project ownership models economically attractive. One model, for example, entails utilities buying and selling electricity from homeowners and running a demand response program, which then aggregates residential demand that is sold into bulk power markets. A capacity market and effective ancillary services market design are needed in order for this ownership model to function.
- ***There remain technology and cost challenges.*** While the technology to deploy NG and RE synergistically is generally commercially available, costs still need to come down for more rapid deployment to occur. For instance, smaller NG

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microturbines that are appropriately sized for single-home applications have low efficiency rates relative to larger microturbines, which can make a project uneconomical at a small scale but could be more economical if socialized into the fully loaded system cost.

- ***Infrastructure needs are significant.*** More NG pipelines are needed to support evolving demand profiles, and transmission is needed to transport RE from resource bases to load centers. This is explored in more depth as its own priority sub-heading, but it is a significant barrier that was identified by workshop participants. Fortunately, the U.S. has a well established tax advantaged infrastructure program through Master Limited Partnerships (MLPs), which are effective investment vehicles for rapidly developing energy infrastructure once a certain threshold of shippers have signed long term contracts.
- ***Cheap NG impacts the economics for renewables.*** When NG prices are low, it can be more difficult for renewables to compete economically. Relatively cheap NG can undermine investments in renewables and slow the uptake of demand response or energy efficiency. At the same time, lower NG prices make NG-RE investments more attractive relative to when NG prices are higher.
- ***Renewables could dampen the economics for NG.*** Renewables may lower wholesale market prices and reduce the hours NG plants have to run in order to serve load. This makes it more difficult for NG generators to recover their costs and has the further impact of potentially stranding higher fixed cost generation assets such as coal and nuclear. Furthermore, as NG meets variable output from renewables, operation and maintenance expenses could increase as plants are cycled more frequently. This could translate into higher and more volatile overall costs for NG plants.
- ***NG-electric market harmonization remains a challenge.*** Increased coordination between the NG and electricity sectors is needed in order to avoid stranded capital and maximize returns on investments. Flexible scheduling and nomination cycles, flexible contracting arrangements between sectors, and the ability to manage schedule changes intra-hour are a few ways in which gas-electric market harmonization could improve. NG-electric market harmonization is explored in more depth as its own identified priority.
- ***Local impacts from siting and operations.*** There remain some concerns with siting large RE projects as well as environmental concerns with NG development, transport, and use. In some cases, technological advances, industry best practices, and system modernization can help address public concerns. For example, for NG developed using hydraulic fracturing, some localities raise concerns about the risk of water contamination, excessive noise, infrastructure build-out, methane leakage, and local air pollution. Addressing these public perception challenges with better data and providing a more accurate picture of the industries' footprints to enhance public acceptance of both NG and RE will be needed in order to effectively pursue NG-RE synergies. Adding to this perception issue is the fact that gas and renewables are often located closer to the load and therefore within the line of sight versus centralized power generation that is out of sight and out of mind.

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Importance of Flexibility and Diversification for Enhancing Resiliency

- ***Together, NG and RE can help improve energy system flexibility and resiliency.*** Increasing penetrations of renewables means an increased need for flexibility, and electricity generation that is based on NG offers increased dispatchability and flexibility. For instance, NG-fired generators can respond to rapid changes in renewable generator output, offering operational flexibility. However, greater coordination is needed between balancing areas to manage variability and reduce curtailment. At the same time, customer resources also add flexibility. Demand response, electric storage, and actively controlled wind resources, for example, can provide responses just as quickly as NG generation, but NG is needed to accommodate sustained, larger changes in load.

- ***Valuing flexibility with proper price signals is critical.*** There are numerous non-market benefits and costs associated with different energy resources, and when these are not quantified, inaccurate price signals can result. One of the non-market benefits is the flexibility provided by NG-fired generation. Because increasing penetrations of renewables affect markets and increase fuel diversity, proper price signals will be critical to reward required flexibility services. Because fast ramping resources are needed for meeting variable output from renewables, payments for faster ramping resources, such as through a capacity payment and a payment for performance, would attach a value to this otherwise non-quantified technological benefit. Valuing reliability and flexibility in NG delivery for NG plants is necessary in order to send proper price signals to the market.[3]

- ***Cost comparisons between technologies must go beyond levelized cost of energy (LCOE) calculations.*** A global LCOE provides a mechanism for comparing energy sources on a level playing field in the power sector, but it omits many factors that generate or detract value, fundamentally altering the economics. For instance, wind and solar might be competitive with NG on an LCOE basis (i.e., capital plus operating costs), but the former may need firming, which adds a cost. Recently, however, some progressive utilities have argued successfully with their public utility commissions to rate base investment directly in gas fields to lower total fuel costs given abundant shale gas supplies. Technical constraints and diversification benefits need to be quantified. Similarly, gas prices add fuel price risk, which adds a cost. Local market and policy conditions are also sometimes ignored in these calculations, which have significant impacts on costs as well.

- ***Portfolio diversification hedges risks.*** There are numerous non-market benefits and costs associated with NG and RE technologies that contribute to their attractiveness but which are not typically included in LCOE calculations. For instance, diversification of the electric generation portfolio reduces risk in general, and this is particularly true for the simultaneous pursuit of both NG and

[3] Another view is to consider energy-only markets. If prices fluctuated up to scarcity pricing, then there would not be a need to create markets for these flexibility services. The difference depends mostly on market structure (e.g., whether the electricity market is regulated). In regulated markets, where short term price signals are limited, there is a need to define services and fulfill them with resource capabilities.

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RE.[4] Electricity mix diversification provides risk-hedging benefits not only at the project level but also at the system level, which contributes to the economic attractiveness of NG and RE technologies. Similarly, both technologies emit less carbon than other fuel sources such as coal, demonstrating an added environmental benefit from diversifying an electricity portfolio and decreasing costs associated with carbon reduction in the face of new policy initiatives. These procurement strategies could potentially add brand value to producers and enhance their "clean" image, thus providing a competitive advantage in adding and retaining customers.

Infrastructure Investment Needs

- ***Business models can capitalize on shared infrastructure investments.*** Additional transmission capacity is needed in order to unlock the potential of both NG and renewables. As demand for NG increases on its own and also because of its need to support increased RE penetration, more NG pipeline will be needed. Similarly, many high resource bases for renewables are located far from load centers, and investments in electrical transmission extensions and improvements are needed in order for power to reach end-users. Some parts of the United States, such as the Midwest, hold abundant NG and renewable resources, but transmission capacity is insufficient for delivering power to end-users in load centers and incumbent utilities are threatened by disruption as well as the impact that it may have on their business models. Transmission infrastructure investments in both NG pipelines and electricity lines are required to open market opportunities for NG and RE in rural areas. Investing in joint transmission corridors to service resource-rich areas could enable exploitation of high quality NG and renewable resources.
- ***Investing in the information infrastructure could also offer significant benefits.*** Obtaining price signals from the market requires better information, communications, and control technology on the power system. These investments are complements and substitutes with pipelines and power lines; complements because they facilitate manifestation of value opportunities on the system and thus create more certainty around investment, and substitutes because better information technology is likely to render at least some generation unnecessary. Thus, there are co-benefits to investing in information and communications technology as well.

Innovative Business Models

- ***Innovative business models are needed to capitalize on the fluctuating market conditions to harness NG-RE opportunities and mitigate potential adverse impacts.*** Utilities across the developed world are facing mounting challenges that create potential barriers to rapid deployment of NG and RE. For example, in the United States, a few supply-demand fundamentals affecting today's market

[4] It is important to note that diversification benefits go well beyond harmonizing only NG and RE. For instance, diversification of RE technologies among themselves (by location, time of generation, and technology type) also has value. In addition, energy efficiency, demand response, and storage also offer diversification benefits. Co-optimization of all clean resources is likely to provide additional benefits.

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include flattening demand, fuel price volatility, environmental and carbon-reducing policies that threaten to make more inefficient power plates obsolete, the NG supply boom, and a demand pull (gas-intense industrial projects such as for methanol, gas-to-liquids, crackers, and ammonia). Furthermore, there is ongoing regulatory uncertainty and a rising commitment to renewables. Innovative business models are needed to capitalize on the fluctuating market conditions to harness NG-RE opportunities and mitigate potential adverse impacts.

Energy Services Provider of the Future and Creating Value for the Customer

- ***Creating value for the customer by focusing on reliability and affordability.*** Distributed energy systems enhance customer value by providing comfort, convenience, and reliability. Public power is increasingly leaning toward customer-service-oriented solutions, shifting to business models that maximize customer value. A key driver for NG and RE synergies will be the ability to aggregate systems and operate them in a way that creates value for the customer. For example, customers place a high value on reliability and affordability. One mechanism for enhancing reliability and affordability in the NG-RE synergies context might be to place more emphasis on NG price stability. Portfolio purchasing strategies (more short-term and long-term gas contracts and less spot market purchases), financial hedges, and physical hedges (through reserve acquisitions and development ventures) can help flatten the NG price peaks, which trickles down to the end-user through electricity pricing. More progressive load servicing entities are embracing these policies.
- ***Growth in customer-connected devices rather than grid-connected devices will lead to customers offering services of value to the power system.*** Customers increasingly want more control of their energy use, and there is a need for facilitating consumer participation in power markets. Today's world is characterized by mandated RE, but tomorrow's world will consist of customer targets to use more RE, and utilities will shift toward more RE use to hedge fuel costs. It will be a customer-connected world, characterized by demand response, distributed generation, and digital technology for energy management. Customer devices and decision-making enable customer-driven services provided directly to the utility or through a third-party aggregator of energy services, who then pay the customer for the value they provide. Growth in customer-connected devices will ultimately allow customers to *offer* services of value to the power system.
- ***Shift basis of pricing from commodities to services.*** As the energy services provider of the future focuses on creating value for the customer, pricing based on services rendered rather than commodities consumed might be more effective. For example, electricity pricing could incorporate a value for clean, reliable power or for the flexibility in NG delivery for NG plants. Pricing that reflects the value of services rather than just the commodity underpinnings might better capture the costs and benefits of supply, delivery, and demand-side resources, while also capturing the opportunities for NG and RE synergies. This would be especially true with a carbon tax.

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Importance of Electric and Gas Market Coordination

- ***Enhancing NG and electric market coordination is required to support increased NG-RE integration.*** NG and electric market coordination entails additional flexibility in scheduling and nomination cycles in some regions and more flexible contracting arrangements between gas and electric sectors. Managing schedule changes intra-hour could contribute to this flexibility. Increased coordination would help maximize returns on investments and introduce potential financing synergies, such as through investing in transmission corridors, enabling deployment of both NG and RE in remote regions that otherwise might not be developed. Communication will play a critical role enabling the coordination of NG and electric markets. For example, communication of operational information between NG pipelines and electric transmission operators would increase sharing of non-public operational information between utilities and pipelines. But either way, last mile distribution investment and upgrades will be necessary to ensure a resilient grid system.

- ***Regional differences in market structures and fuel mixes necessitate a variety of solutions.*** In the wholesale market, responsive resources are needed. Current wholesale market rules are not supportive of responsive resources, and there is no policy or financial incentive for flexible natural gas combined cycle (NGCC) plants. Market rules prevent incentives for NGCC, especially legacy interests, and regional transmission organizations are problematic. On the retail side, each state is unique, and educating regulators about technology transitions is important for enabling successful NG-RE synergies. This is further complicated by the extreme fragmentation in state regulatory policy regimes and their decision-making processes.

Importance of Regulation and Wider Policy Objectives

- ***Market enabling regulation and policy are needed for NG-RE synergistic investments to be favorable.*** The regulatory paradigm needs to change in order to accommodate NG-RE synergies. The structure must allow for investment returns, as energy ultimately is provided by private entities, and policy and regulation need to be more market enabling. Although the hybrid model is emerging as a mechanism for creating customer value, system efficiency improvements and better pricing signals for distributed energy resources could be market enabling for NG-RE synergistic investments. Similarly, integration of NG-RE systems such as microgrids will require new legal frameworks to accompany new ownership structures that may impact property transfer rights.

- ***The Environmental Protection Agency's Clean Power Plan Proposed Rule provides significant flexibility for states to pursue various strategies for reducing their carbon footprint.*** As states must collectively cut power sector emissions by 30% by 2030, they have the flexibility to develop plans for reaching this target, and NG and RE will both be critical components. Educating states on the value of fuel diversity and risk hedging in the context of the Clean Power Plan will help motivate NG-RE synergies.

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Economically Favorable Hybrid Systems

- ***Relative to gas-only and solar-only systems, hybrid NG-RE systems are more economically attractive.*** Depending on location and local market characteristics, hybrid systems often cost less than gas or solar plants on their own, can lower utility revenue requirements, and produce lower rates for customers. This value proposition transpires even without quantifying and incorporating non-economic benefits such as reducing carbon emission, hedging fuel price risk, or improving reliability.[5]

The next section details case study analyses that quantify the value of investing in hybrid NG-RE systems.

[5] Note that there are benefits of co-optimizing all customer resources, not just those consisting of NG and RE solutions. These include energy efficiency, storage, programmatic demand response, etc. and needs such as heat and electricity in accordance with services desired. The hybrid NG-RE solutions are only considered here as an illustrative example through case study analyses.

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Quantifying NG-RE Investments

While recent work provides anecdotal evidence of NG-RE synergies in the power sector (see Lee et al. [2012] and Cochran et al. [2014]), few studies to date quantify the value proposition of investing in systems comprised of both NG and RE. Therefore, one component of JISEA's work stream on NG-RE synergies sought to close this gap by applying economic valuation techniques to hypothetical investment opportunities at the distribution edge as well as from a system-wide perspective. This section briefly summarizes JISEA's work but largely relies on the original research product for methodology details.

Distributed Solutions

Valuing investment opportunities in NG and RE synergistic projects requires a detailed analysis of the complex system interactions, capturing factors such as the electricity load profile, non-electric NG demand (for heating), electricity rate structures, RE output, NG prices, and NG price volatility, each of which affects system operations, costs, and revenue at an hourly level. Accordingly, recent JISEA analysis (e.g., Pless et al. forthcoming) considers hypothetical hybrid NG-RE investment projects relative to their NG-only and RE-only comparable alternatives, characterizing operations at the hourly level over a 25-year project lifetime for residential applications and a 30-year project lifetime for commercial applicatins. Conducting the analysis at the hourly level also allows for the use of location-specific data and an understanding of how various market features impact investment attractiveness.

Pless et al. (forthcoming) apply two techniques—a traditional discounted cash flow (DCF) analysis and a real options analysis (ROA)—to value investments at the project level from a system owner's perspective. Both DCF and ROA are well-vetted economic valuation methodologies and provide different advantages. Traditional DCF analysis allows for clear and tractable interpretation of results with consistent decision criteria based on net present value (NPV) calculations; however, it treats cash flows as deterministic, assumes a static treatment of uncertainty, and results in now-or-never decision making, which is unrealistic as discount rates for generators and utilities change constantly depending on their capital structure and financial strength. In reality, energy investments are characterized by uncertainty and irreversibility within a fluid, stochastic business environment. ROA offers a methodology to account for these attributes (e.g., see Dixit and Pindyck [1994] for a detailed discussion of ROA). Any decision that involves sunk costs can be viewed in a ROA framework.

One potential synergy for generating electricity at the distribution edge is that of a stand-alone system composed of natural gas microturbines[6] and solar photovoltaics (PV), two technologies that are commercially available today. The hypothetical case studies consider applications for a single home and for a critical services building (a hospital) in

[6] Microturbines can run continuously or on-demand, can be installed individually or via a multi-pack, and can stand alone or connect to a grid. They have been commercially applied in residential and commercial buildings, and they can be generally scaled as needed (with a loss of electrical efficiency as they are scaled down).

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Suffolk County, New York and Waco, Texas, which exhibit contrasting market structures and end-user load profiles.[7]

The case study analysis does not optimize system design or operations for a given site, nor does it consider flexibility in load or other complementary technological and behavioral changes. Rather, it focuses on modeling inputs that capture the different resource risk profiles, namely NG price volatility and renewable output variability. Thus, the analysis assumes given system sizes for solar PV—4 kW (DC) and 1.4 MW (DC) for a single-home residential application and a hospital application, respectively. Location-specific hourly solar output for one year was simulated using the National Renewable Energy Laboratory's (NREL's) PVWatts tool,[8] and a performance degradation rate of 0.5% annually is assumed to account for aging system components. Furthermore, the case studies assume that the distributed generation (DG) system fully meets both electricity and non-electric NG demand. Therefore, an appropriate NG microturbine size is calculated according to industry standard efficiency assumptions and a 10% reserve requirement.[9]

The analyses assume that 100% of solar output is consumed on an hourly basis, and the NG microturbines account for excess electricity demand as well as non-electric (heating) NG demand. Location-specific market characteristics are implemented, which impact cost and revenue streams, such as utility electricity rate structures (both standard and time-of-use (TOU)), NG utility rate structures, the option for net metering, and different NG price paths (characterized by increasing levels of volatility). The model's financing assumptions follow NREL's System Advisor Model (SAM) documentation (NREL 2014); the equations used to calculate the financial metrics are based on the definitions and methods described in Short et al. (1995).

Select sets of results are presented here. The objective is to compare the distributed generation (DG) investment options between technology configurations as well as to a business-as-usual (BAU) case, which is the case of no onsite system being installed. In other words, under BAU, electricity and NG are purchased from the local utility as usual,

[7] Note that there are numerous potential system level solutions to consider, including both technological and behavioral components. However, this analysis focused on just one potential configuration for illustrative purposes through NG-RE hybrid system case study analyses, assuming a passive load and no other complementary investments, such as demand response or energy efficiency, to further co-optimize the systems.

[8] PVWatts uses hourly solar resource data that describe solar radiation and meteorological conditions at site-specific locations. Specifically, PVWatts uses the National Solar Radiation Database (1961–1990) (TMy2) data site nearest the system location. The PVWatts default values are assumed for the solar PV system.

[9] Microturbines are driven by small-scale gas turbines and their electrical efficiencies generally range from 26% to 33% (without combined heat and power [CHP]) and can achieve thermal efficiency of up to 85% with CHP. Technology and performance assumptions in Pless et al. (forthcoming) are based on reported figures from Capstone Turbine Corporation, which captures roughly 80% of the U.S. microturbine market. The smallest microturbine sold by Capstone is 30 kW; however, they can be scaled to almost any size. Net heat rates range from 11,800 Btu/kWh to 14,700 Btu/kWh, where higher heat rates suggest less efficient systems. Microturbines for the residential applications are assumed to perform at an 80% efficiency rate with CHP, 13,000 Btu/kWh heat rate, and 1,050 Btu/scf fuel heat content. For commercial applications, the assumptions are 80% efficiency, 12,000 Btu/kWh heat rate, and 900 Btu/scf fuel heat content.

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so BAU consists only of cash outflows (i.e., 100% of electricity and NG bills), whereas cash inflows are captured in the other cases because utility bills are offset by the onsite generation.[10]

Valuations are presented in nominal dollars, and negative values are shown in parentheses and red text. Results from both DCF and ROA can be interpreted similarly: a positive NPV (for DCF) or real options value (ROV) suggests that the investment is attractive whereas negative NPVs mean that the project should not be pursued.[11] However, since the objective is to compare the investments to each other as well as to BAU (as opposed to invest or not invest), the decision criterion is slightly different. Generally, more (less) positive (negative) NPVs or ROVs represent the more economically attractive investment, so a negative value doesn't necessarily mean that the investment shouldn't be pursued if the value is in fact less negative than the BAU case. The less negative the NPV, the more savings achieved relative to BAU. The NPV with the highest value relative to comparable systems (and BAU) indicates the most economically attractive investment option.

The DCF and ROA results for a single-home DG system located in New York are presented in Table 1. These figures compare systems to BAU under either a standard or TOU electricity rate structure and with the option for net metering solar output. A baseline (calibrated) volatility NG price path is assumed, and due to the project's location, non-electric NG demand is relatively high.

For this application, NPVs and ROVs are positive for the hybrid NG-RE system, even without financial incentives for the solar component and under high NG price volatility. Alternatively, the NG-only and RE-only configurations produce negative NPVs and ROVs, however investing in either single-technology DG system is still more economically attractive than BAU. For instance, note that the figures for the RE-only cases are low because they include cash outflows for residential electricity demand, however they are less negative than those for BAU, suggesting savings from investing in a RE-only system. As expected, the investment is even more attractive when incentives for solar are available, however they aren't required for the investment to payoff relative to BAU. Under standard electricity rates and without incentives for solar, the hybrid NG-RE investment would take 14.46 years to payoff (or 6.45 years with incentive). These figures are 12.6 and 4.27, respectively, under a TOU electricity rate structure and when net metering is available.

[10] Two variations of RE-only are shown for the case of Suffolk County, NY—one including the negative cash flows of non-electric NG load accounted for by the local utility, and one including only cash flows for electricity demand (non-electric NG payments to the utility aren't included as cash flows). For the case of Waco, TX, only the former is provided since there exists no non-electric NG demand.
[11] Because ROA inherently places a value on "options"—or in other words, the option to expand a project or delay an investment—it is possible to obtain a negative NPV but a positive ROV. Although ROA is a bit less tractable, using both methodologies provides robustness in the results.

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Table 1. DCF and ROA Valuations for a Single Home DG System Located in Suffolk County, New York (baseline NG price volatility) (nominal dollars)

System Design	BAU	NG-Only	Solar+Gas	BAU	NG-Only	RE-Only (heating included)	RE-Only (electricity only)	Solar+Gas
Electricity Rates	Standard	Standard	Standard	TOU	TOU	TOU	TOU	TOU
Net Metering	No	No	No	Yes	Yes	Yes	Yes	Yes
Initial Investment	$0	$34,320	$22,080	$0	$34,320	$14,800	$14,800	$17,920
NPV	($67,828)	($8,645)	$2,694	($66,491)	($9,981)	($64,700)	($38,181)	$5,061
NPV (with incentives)			$8,526			($60,889)	($34,369)	$9,750
Payback (years, no incentives)		21.93	14.46		23.1	>24	>24	12.60
Payback (years, solar incentives)			6.45			>24	>24	4.27
Option Value (no incentives)		$5,068	$24,426		$1,077	($42,285)	($33,682)	$47,972

Similarly, for the case of a commercial critical services building (a hospital) located in Suffolk County, NY, the hybrid NG-Re systems consistently produce positive NPVs and ROVs (and generally more favorable outcomes than the single technology alternatives), and the payback periods are much lower than the residential applications given the scale of investment (see Table 2). Investing in a hybrid NG-RE system pays off in 4.98 years without incentives (3.25 years with incentives) under a standard electricity rate structure, and respectively, 4.54 years without incentives (and 2.96 years with incentives) under TOU rates and net metering. On the other hand, while the hybrid NG-RE systems are more attractive than their single-technology alternatives with solar incentives, the NG-only system is more attractive when incentives are available. Again, all DG systems are economically favorable relative to BAU.

Table 2. DCF and ROA Valuations for a Critical Services Building (Hospital) DG System Located in Suffolk County, New York (baseline NG price volatility) (nominal dollars)

System Design	BAU	NG-Only	Solar+Gas	BAU	NG-Only	RE-Only (heating included)	RE-Only (electricity only)	Solar+Gas
Electricity Rates	Standard	Standard	Standard	TOU	TOU	TOU	TOU	TOU
Net Metering	No	No	No	Yes	Yes	Yes	Yes	Yes
Initial Investment	$0	$2.21M	$5.85M	$0	$2.21M	$3.6M	$3.6M	$5.85M
NPV	($17.9M)	$8.10M	$6.99M	($18.0M)	$8.23M	($15.9M)	($13.9M)	$7.12M
NPV (with incentives)			$8.46M			($14.9M)	($12.9M)	$8.59M
Payback (years, no incentives)		2.51	4.98		2.24	>30	>30	4.54
Payback (years, solar incentives)			3.25			>30	>30	2.96
Option Value (no incentives)		$104M	$119M		$105M	($16.7M)	($15.6M)	$121M

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When considering a similar analysis for a case based in Waco, Texas, the findings are less favorable but consistent with the patterns found for Suffolk County, New York. Table C1 presents the results for a single-home application in Waco and Table C2 presents results for a commercial application in Appendix C. The results are less favorable because of the low non-electric NG load in Texas compared to the high NG load heating needs found in regions such as New York, where significantly higher utility bills are offset by installing DG. In other words, investments in DG systems including NG microturbine components become more attractive when NG demand is higher because the customer avoids significantly higher NG payments to local utilities. The systems still offer scale economies, however, and the payoff is more attractive for commercial systems even with lower non-electric NG demand.

The main finding from this analysis is that the hybrid system is consistently more attractive than the RE-only and NG-only alternatives, all else equal. In some cases, NG-only systems are favored over hybrid systems when incentives for solar are not available. Perhaps most importantly, all DG systems are found to be more economically attractive compared to BAU, and DG investments are more attractive under TOU electricity rate structures and when net metering is available, highlighting the importance of policy for determining payoff. These results hold true when using both NPV and ROV valuation metrics.

Lastly, this case study analysis did not consider other benefits associated with investing in a DG system for standalone applications. Quantifying features such as reliability benefits and ancillary services would enhance the economic attractiveness of these investments. Furthermore, this exercise was not meant to fully capture the system level co-optimization benefits of pairing technologies, behavioral change, and diversification more broadly. There are numerous other technology combinations as well as customer-driven solutions, such as load flexibility, storage, energy efficiency, and more, which could further contribute to the benefits of investing in distributed solutions.

System-Wide Perspective

Going beyond project-level synergies, NG and RE together also offer benefits at the system level. This section summarizes the value proposition of NG and RE generation from a system-wide perspective using output data from the *Renewable Electricity Futures* (REF) study, which examined the feasibility of meeting electricity demand in 2050 with greater penetrations of RE.

The REF study compared the capacity and generation required to meet demand in the United States under several scenarios characterized by different RE penetration targets, ranging from 20% to 90% by 2050 (NREL 2012). JISEA's analysis used data from the 80% Incremental Technology Improvement scenario, which utilizes NG generation for meeting about 30% of the total load in 2012 when RE generation is low and ramps down NG generation as RE generation and capacity increases (Mai et al. 2014).

To analyze the profitability of NG and RE in a system-wide model, JISEA focused on a case study of California and implemented a DCF analysis. The effects of varying magnitudes of capacity payments for NGCC capacity on profit were also analyzed in

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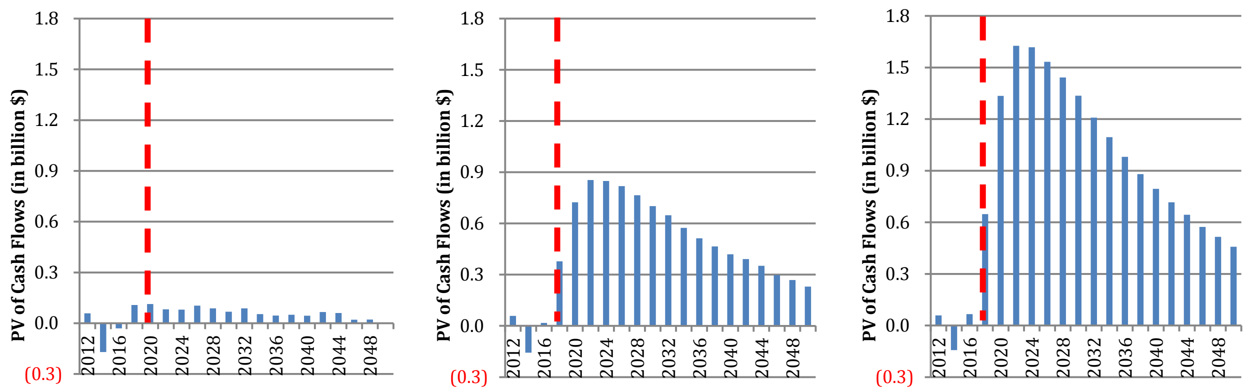
order to compare energy-only markets to energy plus capacity markets. Capacity payments were only awarded to dispatchable electricity sources such as NG, and the payments are for the available capacity after generation.

Figure 1 shows the present value of biennial cash flows received only from NGCC from 2012 to 2050. Figure 1a shows the cash flows without capacity payments and Figures 1b and 1c show cash flows with medium and maximum payments for NGCC capacity, respectively.[12] The NPV is positive for all cases in Figure 1, which means NGCC is profitable even without capacity payments. However, with medium capacity payments the NPV is almost 10 times greater than without payments, and with maximum capacity payments the NPV is almost 20 times greater than without payments. The break-even year (represented by the red dashed line) is 2020 for the case without capacity payments and 2018 for both of the cases with capacity payments.



(a) No capacity payments

NPV = $1.91 billion

(b) Medium capacity payments for NGCC

NPV = $18.34 billion

(c) Maximum capacity payments for NGCC

NPV = $34.77 billion

Figure 1. Present value of cash flows (2013$) from NGCC with no capacity payments (a), medium capacity payments (b), and maximum capacity payments (c), 2012-2050

Source: JISEA calculations. Forecasted wholesale electricity prices from NW Council (2014). Other inputs and assumptions are from Mai et al. (2014).

Figure 2 combines the present value of biennial cash flows received from NGCC and wind, without financial incentives. Although other RE and non-RE sources are important for the electricity system to operate, JISEA focuses on the profitability of wind and NGCC in order to examine the synergies between NG and RE. Without capacity payments, the NPV of all cash flows of wind and NGCC from 2012 to 2050 are negative. However, with medium capacity payments, the NPV is positive and the break-even year is in 2036. Furthermore, increasing the capacity payments from medium to the maximum amount doubles the NPV and moves the break-even point to the year 2026.

[12] Capacity payments are calculated as a percentage of the revenue from energy per capacity value, where maximum capacity payment is equal to the revenue for energy per capacity value and medium capacity payment is equal to half of the revenue for energy per capacity value. Capacity value is calculated as the maximum capacity factors—the percentage of electricity generated in a year relative to the maximum electricity that could be generated—during the entire time period.

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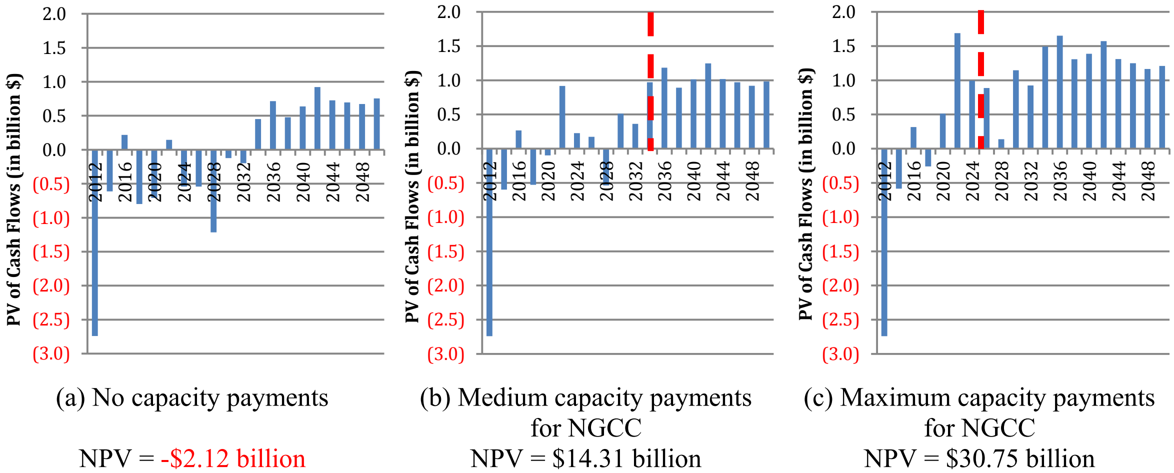

Figure 2. Present value of cash flows (2013$) from NGCC and wind with no capacity payments (a), medium capacity payments (b), and maximum capacity payments (c), 2012-2050

Source: JISEA calculations. Forecasted wholesale electricity prices from NW Council (2014). Other inputs and assumptions from Mai et al. (2014).

This system-wide financial valuation is meant to illustrate one case study—in California—that utilizes NG and wind in a synergistic manner. An analysis that examines the synergies between NG and wind in another region might find different results, depending on the capacity investments, generation, and regional wholesale price. However, this broad view shows the importance of policy and market designs on the profitability of investing in NG and RE as complements.

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Conclusions and a Pathway Forward: Areas for Further Investigation

Ensuring the resilience, reliability, flexibility, and affordability of the U.S. electric grid is increasingly important as the country faces climate change threats and an aging infrastructure. In order to achieve and sustain these system attributes, however, major investments in a modern 21st century electric grid are needed, and solution implementation is complex. Resource availability, market design, regulation, and policy vary significantly across regions, and as the drivers for scaling-up opportunities evolve, there is a need for innovative solutions. Technology, policy, and finance will each contribute to the pathway forward.

While there is no panacea, one potential mechanism identified by stakeholders for moving toward these objectives is the opportunity for NG and RE to work together as complements. The United States is amidst an energy transition characterized by a relative abundance of both domestic unconventional NG and renewable energy resources, which contribute to energy independence, carbon mitigation, and economic growth. Strategically, synergies between NG and RE exist at multiple levels, from tightly coupled, hybrid systems that optimize assets (e.g., wind turbines with NG-compressed air energy storage) to loosely coupled investment portfolios that address business and financial risks through asset diversification. Today, synergies between NG and RE are not just intangible concepts. Rather, there are many real-world examples that exist on both project and system levels, providing success cases and a growing appreciation for considering an entire portfolio of electricity options.

However, there remains room for continued exploration of the NG-RE synergies concept and solution space. For instance, although JISEA conducted in-depth analyses of hypothetical case studies to quantify the value proposition of investing in NG and RE together on a project level as well as a system level, analyses of real-life case studies is warranted to better understand the mechanisms for generating the highest possible returns. Similarly, continued analyses of the benefits of diversification for portfolio risk hedging and valuing the flexibility provided by rapidly ramping NG plants are needed. Quantifying the non-market benefits and costs of NG-RE project characteristics more generally, such as reliability benefits and the value of flexibility, is needed for investment valuations to adequately reflect the true value contributed by NG and RE.

From a policy and regulation perspective, market-based instruments are needed to move NG-RE synergies to the next step. There appears to be a relatively large suite of regulatory and market barriers that are inhibiting a greater penetration of synergistic solutions. In particular, these include electric-gas market coordination challenges and infrastructure investment needs. Business models are evolving, but there are still regulatory hurdles to overcome. Future work could explore potential policy and regulation scenarios that might enable deployment of hybrid systems, such as microgrids or schemes that could enable better gas-electric market coordination. Research could also address the planning, market, and operations futures that would provide incentives for transmission investments and potential mechanisms to pay for retiring obsolete fossil plants.

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Lastly, as the market moves toward distributed energy systems that enhance customer value by providing comfort, convenience, and reliability, operating systems that create more value for the customer increasingly will be a priority. This will require a better understanding of how customer demand segments are evolving and what tools might help better manage risks. Exploring the potential for new customer-connected devices to facilitate consumer participation in power markets will contribute to this transition.

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Appendix A: Participant Acknowledgments

Participants of the *Synergies of Natural Gas and Renewable Energy: 360 Degrees of Opportunity* workshop series made numerous and substantial contributions to this work. Participants included industry and policy thought leaders in NG and RE markets, representing a diverse sampling of stakeholders. A full list of those who participated is provided here:

- Melissa Adams, Washington Gas
- Kip Averitt, Averitt and Associates
- Doyle Beneby, CPS Energy
- Shawn Bennett, Federal Energy Regulatory Commission
- Ron Binz, Public Policy Consulting
- Mark K. Boling, Southwestern Energy Company
- Charlie Blanchard, Bloomberg New Energy Finance
- Andrew Blum, National Governors Association
- Terry Boston, PJM Interconnection
- Erica Bowman, America's Natural Gas Alliance
- Michael Brower, ACORE
- Mark Brownstein, Environmental Defense Fund
- Blaine Bull, Vianovo
- Allen Burchett, ABB
- Kathryn Clay, AGA
- Jaquelin Cochran, National Renewable Energy Laboratory
- Steve Corneli, NRG Energy
- Paul DeCotis, West Monroe Partners, LLC
- TJ Deora, IHS Energy
- Reid Detchon, UN Foundation
- John De Yonge, Ernst & Young, LLP
- Michel di Capua, Bloomberg New Energy Finance
- Bob Dixon, Global Environment Facility
- Mike Eckhart, Citigroup Capital Markets, Inc.
- Amy Farrell, America's Natural Gas Alliance
- Todd Foley, ACORE

- Tom Foreman, GCPA
- Peter Fox-Penner, The Brattle Group
- Anne George, ISO-NE
- Kevin Hanson, Electric Reliability Council of Texas
- Mari Lu Hastings, Mitchell Foundation
- Mike Hogan, Regulatory Assistance Project
- Craig Johnson, Ernst & Young, LLP
- Edward Johnston, GTI
- Richard Kaelin, GTI
- Richard Kauffman, Office of the Governor, New York
- Sherman Knight, Competitive Power Ventures Holdings, LLC
- Sarah Ladislaw, CSIS
- Ian Lange, Colorado School of Mines
- Ronald Lehr, Consultant
- Carl Linvill, Regulatory Assistance Project
- Elizabeth Lippincott, Vianovo
- Brian Lloyd, Public Utility Commission of Texas
- Jeffrey Logan, National Renewable Energy Laboratory
- Missy Mandell, Mandell and Associates
- Paul Marcon, BTG Pactual
- Jim Marston, EDF
- Granville Martin, JPMorgan Chase
- Buck Martinez, FPL
- Thomas Massaro, New Jersey Natural Gas Company
- Richard McMahon, Edison Electric Institute
- Nils Mellquist, Deutsche Bank
- Richard Meyer, AGA
- David Mohler, Duke Energy
- Juan Pablo Moncayo, Highstar Capital
- Rick Murphy, AGA
- Christopher Namovicz, U.S. Energy Information Administration

- Nelson Nease, Nelson H. Nease, P.C.
- Jerry Noland, CenterPoint Energy
- Judy O'Brien, The Keystone Center
- Tom Plant, Center for the New Energy Economy
- Jacquelyn Pless, Joint Institute for Strategic Energy Analysis
- Bill Ritter, Center for the New Energy Economy
- Scott Sarazen, Ernst & Young, LLP
- Rich Sedano, Regulatory Assistance Project
- Saurin Shah, Neuberger Berman, LLC
- Ira Shavel, The Brattle Group
- Rick Shelby, Gas Turbine Association
- Dan Shelledy, Wartsila North America
- Lenae Shirley, Power Angels
- Kyle Simpson, Hogan Lovells
- Kevin Smith, Goldman Sachs
- Raiford Smith, CPS Energy
- Steve Stolze, Ernst & Young, LLP
- Terry Thorn, JKM Consulting
- Sue Tierney, Analysis Group
- Dan Utech, CEQ
- Frank Verrastro, CSIS
- Michael Webber, Webber Energy Group, UT
- Brian Weeks, GTI
- Jeff Weiss, Distributed Sun, LLC
- Jamie Wickett, Hogan Lovells
- John Wile, Ernst & Young, LLP
- Yingxia Yang, Brattle Group
- Anthony Yuen, Citi Research
- Ali Zaidi, CEQ
- Owen Zinaman, National Renewable Energy Laboratory.

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Appendix B: Forum Series Agendas

The *NG-RE 360 Degrees of Opportunity Forum Series* built upon previous work conducted by JISEA and its partner institutions that explored the system-level solutions, platforms for partnership, and new business models that NG and RE can offer. Workshops were held in three different locations: New York City, focusing on the investment community; Washington, DC, focusing on national policy; and Texas, where both NG and RE play a significant role in the economy and there exists significant latent potential for more synergistic use.

The full agendas for the three workshops are provided here.

Agendas
Synergies of Natural Gas and Renewable Energy: 360 Degrees of Opportunity

New York City Edition; Focus on Business and Finance; Hosted by Bloomberg New Energy Finance
July 1, 2014

8:00 a.m. – 8:30 a.m.	**Continental Breakfast**
8:30 a.m. – 8:45 a.m.	**Welcome Remarks and Introductions** **Doug Arent**, Executive Director, Joint Institute for Strategic Energy Analysis **Michel di Capua**, Head of Research, Bloomberg New Energy Finance **Scott Sarazen (Facilitator)**, Global Cleantech Markets Leader, Ernst & Young, LLP
8:45 a.m. – 10:00 a.m.	**Session 1** **Natural Gas and Renewable Energy Synergies: Challenges and Opportunities** **Natural Gas Market Perspectives** (10 min): **Charlie Blanchard,** Lead Natural Gas Analyst, Bloomberg New Energy Finance **Presentation** (15 min): **Sue Tierney**, The Analysis Group **Responses** (10 min each): What are the barriers to and opportunities of synergies from various perspectives? **Mark Brownstein**, Associate Vice President and Chief Counsel, Environmental Defense Fund **Yingxia Yang**, Associate, The Brattle Group **Moderated Discussion** (30 minutes) *Objective: Frame the overarching roles that NG and RE can play in achieving a resilient, low-cost energy future. Provide an equal balance of information-sharing and discussion from a diverse base of views.*

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10:00 a.m. – 10:30 a.m.	**Networking/Coffee Break**
10:30 a.m. – 12:00 p.m.	**Session 2** **The Business Case for NG-RE Synergies: Investment and Finance Options** **Presentation** (20 min): **Anthony Yuen**, Global Energy Strategist, Citigroup Research **Responses** (10 minutes each): How can investors harvest value-added revenue streams by linking together NG and RE projects? What policy options can help catalyze this linkage? **Steve Corneli**, Senior Vice President, NRG **Paul DeCotis,** Director, Energy & Utilities Practice, West Monroe Partners, LLC **Richard Kauffman**, Chairman of Energy and Finance for New York, Office of the Governor **Moderated Discussion** (40 minutes) *Objective: Highlight how new financing options, energy system operational changes, and information technology can open up co-investment opportunities, and identify what's needed to catalyze such pairings.*
12:00 p.m. – 1:00 p.m.	**Working Lunch**

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1:00 p.m. – 2:15 p.m.	**Session 3** **The Energy Service Provider of the Future: Issues and Opportunities for Gas and Renewables** **Presentation** (15 min): **Ron Binz**, Founder, Public Policy Consulting **Responses** (10 minutes each): How can energy service providers position themselves for the current and coming changes resulting from increasing shares of NG and RE, and other sweeping changes in today's energy sector? What are the market design, operational and related investment options that allow utilities, merchant generators, energy service companies and others to earn adequate ROI's when wholesale markets are increasingly dominated by NG, RE, EE and demand response? How can risk over uncertain federal policy be mitigated? **Richard McMahon**, Vice President, Edison Electric Institute **Tom Plant**, Senior Policy Advisor, Center for the New Energy Economy, Colorado State University **Rich Sedano,** Principal and Director of U.S. Programs, Regulatory Assistance Project **Moderated Discussion** (30 minutes) *Objective: Provide perspectives on how regional markets are evolving and what that means for today's utilities. Explore options to prepare to become utilities of the future, within the context of synergistic utilization of natural gas and renewable energy.*
2:15 p.m. – 2:30 p.m.	**Conclusions: Next Steps and Action Plan**

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Washington, D.C. Edition; Focus on Policy and Partnerships

Hogan Lovells
555 Thirteenth Street, NW, Washington, DC
Fulbright East Conference Room (13th Floor)
July 25, 2014

8:30 a.m. - 9:00 a.m.	**Continental Breakfast**	
9:00 a.m. – 9:15 a.m.	**Welcome Remarks and Introductions** **Kyle Simpson**, Hogan Lovells **Doug Arent**, Joint Institute for Strategic Energy Analysis **Judy O'Brien (Facilitator)**, Senior Associate; Director, Keystone Energy Board, The Keystone Center	
9:15 a.m. – 10:30 a.m.	**Session 1** **Natural Gas and Renewable Energy Synergies: Challenges and Opportunities** **Special Insights, Dan Utech,** Director for Energy and Climate Change, Domestic Policy Council, Council on Environmental Quality **Responses** (10 min each): What are the barriers to and opportunities of synergies from various perspectives? **Jaquelin Cochran,** NREL **Sarah Ladislaw**, CSIS **Eddie Johnston**, GTI **Moderated Discussion** (30 minutes) *Objective: Frame the overarching roles that NG and RE can play in achieving a resilient, low-cost energy future. Provide an equal balance of information-sharing and discussion from a diverse base of views.*	
10:30 a.m. – 11:00 a.m.	**Networking/Coffee Break**	

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11:00 a.m. – 12:30 p.m.	**Session 2** **Policy and Partnerships: Current Barriers and Future Opportunities for NG-RE Synergies** **Presentation** (20 min): **Gov. Bill Ritter**, Colorado State University **Responses** (10 minutes each): Given the goals of the President's Climate Action Plan, where are the opportunities to remove policy and regulatory barriers allowing greater synergistic use of NG and RE? How might existing or new partnerships help leverage these efforts? **Amy Farrell**, ANGA **Michael Brower**, ACORE **Terry Boston**, PJM **Moderated Discussion** (30 minutes) *Objective: Highlight how new policy options, market changes, and regulation can open up co-investment opportunities, and identify what's needed to catalyze such pairings. What new partnerships can help leverage this?*	
12:30 p.m. – 1:00 p.m.	**Working Lunch**	

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

1:00 p.m. – 2:15 p.m.	**Session 3** **The Energy Service Provider of the Future: Issues and Opportunities for Gas and Renewables** **Presentation** (15 min): **Ronald Lehr**, Consultant **Responses** (10 minutes each): How can energy service providers position themselves for the current and coming changes resulting from increasing shares of NG and RE, and other sweeping changes in today's energy sector? What are the market design, operational and related investment options that allow utilities, merchant generators, energy service companies and others to earn adequate ROI's when wholesale markets are increasingly dominated by NG, RE, EE and demand response? What role and policy and regulation play in enabling and enhancing this future? **Richard F. McMahon**, Edison Electric Institute **David Mohler**, Duke Energy **Peter Fox-Penner**, The Brattle Group **Moderated Discussion**: 30 minutes *Objective: Provide perspectives on how markets are evolving and what that means for today's utilities. Explore options to prepare to become energy service providers of the future, within the context of synergistic utilization of natural gas and renewable energy.*	
2:15 p.m. – 2:30 p.m.	**Conclusions: Next Steps and Action Plan**	

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San Antonio, Texas Edition; Focus on Gas and Renewable Interface Issues in Texas
November 6, 2014
Westin Riverwalk (420 W Market St, San Antonio, TX)

8:30 a.m. - 9:00 a.m.	**Continental Breakfast**	
9:00 a.m. – 9:10 a.m.	**Welcome Remarks and Introductions** **Doug Arent**, Joint Institute for Strategic Energy Analysis	
9:10 a.m. – 10:00 a.m.	**Keynote Address** **Doyle Beneby**, CPS Energy	
10:00 a.m. – 10:50 a.m.	**Session 1** **Natural Gas and Renewable Energy Synergies: Challenges and Opportunities** *Objective: Frame the overarching roles that NG and RE can play in achieving a resilient, low-cost energy future. Provide an equal balance of information-sharing and discussion from a diverse base of views.* **Presentation** (10 min): **Michael Webber,** University of Texas **Responses** (10 min each): What is the importance of NG and RE synergies, and where do and can they occur? What are the barriers to and opportunities of synergies from various perspectives? **Jim Marston**, Environmental Defense Fund **Richard Meyer,** American Gas Association **Kip Averitt**, Former Texas State Senator **Moderated Discussion** (20 minutes)	
10:50 a.m. – 11:15 a.m.	**Networking/Coffee Break**	

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11:15 a.m. – 12:30 p.m.	**Session 2** **Analytic Insights: NG-RE Synergies** *Objective: Understand key analysis questions in gas and renewable space, and what the barriers are to answering them. Facilitate discussion around various studies presented; provide feedback and additional questions.* **Presentation** (20 min): **Ira Shavel,** Brattle Group **Presentation** (20 min): **Jacquelyn Pless**, JISEA **Responses** (8 minutes each): What is the landscape of the opportunity space for natural gas and renewable synergies in distribution and wholesale markets? What are the key barriers to future development? What might future analyses look like in this space to inform the dialogue? **Nelson Nease**, Nelson Nease LLC and Texas Clean Energy Coalition **Carl Linvill**, Regulatory Assistance Project (RAP) **Brian Lloyd**, Public Utility Commission of Texas **Moderated Discussion** (30 minutes)	
12:30 p.m. – 1:00 p.m.	**Lunch**	

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<table>
<tr><td>1:00 p.m. – 2:15 p.m.</td><td>Session 3

The Role of Gas and Renewables in Texas

Objective: Provide perspectives on how Texas market is evolving and what that means for local stakeholders. Explore options to prepare for increased synergistic utilization of natural gas and renewable energy.

Presentation (15 min): Kevin Hanson, ERCOT

Responses (10 minutes each): What are the key trends in Texas with respect to Gas and Renewables? How can Texas stakeholder position themselves for the current and coming changes resulting from increasing shares of NG and RE? and other sweeping changes in today’s energy sector? What are the regulatory, market design, operational and related investment options that allow utilities, merchant generators, energy service companies and others to earn adequate ROI’s when wholesale and distribution markets are increasingly dominated by NG, RE, EE and demand response? What role can policy play in enabling and enhancing this future?

Mark Boling, Southwest Energy
Dan Shelledy, Wärtsilä North America, Inc.
Tom Plant, Center for New Energy Economy

Moderated Discussion: 30 minutes</td><td></td></tr>
<tr><td>2:15 p.m. – 2:30 p.m.</td><td>Conclusions: Next Steps and Action Plan</td><td></td></tr>
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Appendix C: Supplementary Results Tables from Quantification Exercise

Table C1. DCF and ROA Valuations for a Single Home Residential Application Located in Waco, TX (baseline NG price volatility) (nominal dollars)

System Design	BAU	Gas Only	Solar Only	Solar+Gas	BAU	Gas Only	Solar+Gas
Electricity Rates	Standard	Standard	Standard	Standard	TOU	TOU	TOU
Net Metering	No	No	No	No	Yes	Yes	Yes
Initial Investment	$0	$11,440	$13,200	$24,640	$0	$11,440	$24,640
NPV	($24,527)	($7,961)	($17,942)	($10,652)	($29,089)	($3,399)	($6,090)
NPV (with incentives)			($16,642)	($6,178)			($671)
Payback (years, no incentives)		>24	>24	>24		20.49	20.60
Payback (years, solar incentives)			>24	17.6			11.55
Option Value (no incentives)		($8,958)	($26,094)	($13,737)		$3,092	($5,439)

Table C2. DCF and ROA Valuations for a Critical Services Building (Hospital) DG System Located in Waco, TX (baseline NG price volatility) (nominal dollars)

System Design	BAU	Gas Only	Solar Only	Solar+Gas	BAU	Gas Only	Solar+Gas
Electricity Rates	Standard	Standard	Standard	Standard	TOU	TOU	TOU
Net Metering	No	No	No	No	Yes	Yes	Yes
Initial Investment	$0	$3.3M	$3.64M	$6.95M	$0	$3.3M	$6.95M
NPV	($13.0M)	$1.7M	($9.4M)	($320,710)	($15.6M)	$2.35M	$933,980
NPV (with incentives)			($8.0M)	$1.96M			$3.2M
Payback (years, no incentives)		8.82	>30	15.98		7.46	12.27
Payback (years, solar incentives)			>30	6.92			5.06
Option Value (no incentives)		$35.6M	($12.9M)	$36.5M		$53M	$48.2M

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