Orange & Rockland

Edwin J. Ortiz

December 4, 2015

VIA ELECTRONIC MAIL

Honorable Irene Kim Asbury
Secretary of the Board
New Jersey Board of Public Utilities
44 South Clinton Avenue
Trenton, NJ 08625

EMPUpdate@bpu.state.nj.us

Re: Comments on Energy Master Plan

Rockland Electric Company ("RECO") appreciates the opportunity to comment on the Draft New Jersey 2011 Energy Master Plan Update ("Draft Update")[1], and the concepts and goals reflected in on the 2011 New Jersey Energy Master Plan ("EMP"). We offer the following comments in reply to the Board of Public Utilities ("Board") request for comments, with a focus on smart meter deployment.

RECO is fully supportive of the EMP, the overarching goals identified in the EMP and the plan for action ("Action Plan") that it establishes. One goal of the Action Plan is to consider expanded implementation of smart meters in an effort to gradually expand real-time pricing to customers with lower energy demand in order to encourage behavioral changes that result in wiser energy use and reduced retail prices for all residents. The Draft Update recommends expanding the focus of the goal to include distribution automation ("DA") and smart grid ("SG"). RECO strongly supports the consideration of smart meter deployment in the Draft Update, and offers that AMI deployment, including smart meters, is a technology that can broadly improve the energy landscape in New Jersey. In addition, AMI can facilitate the achievement of the broad-based goals established in the EMP.

AMI systems with smart meters have been widely deployed in the U.S., with smart meters installed at more than 50% of U.S. households. Smart meter technologies have expanded and matured significantly in the last five years, and this maturity includes the development of consistent specifications and standards, as well as, proactive approaches to cyber security issues which the EMP goal foresaw. The result is a current opportunity for New Jersey to, not only take advantage of the many AMI technology improvements, but also to benefit from proven AMI deployment approaches, that include efficient meter deployment strategies, effective outage

[1] In addition, RECO is joining in the comments on the Draft Update submitted by the New Jersey Utilities Association on behalf of its energy utility members.

management system integration, tested and proven cyber security measures and customer education and outreach strategies. AMI project costs, particularly around integration efforts with legacy information technology systems have been reduced through the development of consistent integration modules, consistent data synchronization processes and integration road maps that combine data from DA and AMI.

AMI is an established and proven technology. Key benefit areas include increased operational efficiencies, enhanced customer service, customer engagement as regards energy efficiency (e.g., customers who desire to manage their energy needs will have the capability to do so), positive impacts on the environment (e.g., reduced greenhouse gases), demand reduction (e.g., through the ability for customers to manage their home appliances remotely), more informed customer choice of energy providers and improved communication and service restoration during major storm events

The November 2014 US Department of Energy report on the Smart Grid Investment Grant Program[2] (which includes AMI) noted:

> Outage management approaches that used smart grid technologies accelerated service restoration and limited the number of affected customers during major recent storms. Utilities required fewer truck rolls during restoration and used repair crews more efficiently, which reduced utility restoration costs and total outage time. Business and residential customers experienced fewer financial losses, as shorter outage time limited lost productivity, public health and safety hazards, food spoilage, and inconvenience from schedule disruptions.

The October 8, 2013 Smart Grid Consumer Collaborative report on Smart Grid Economic and Environmental Benefits[3] (which also includes AMI) provides detailed benefit information on time varying rates, energy choice, energy efficiency, outage management and reliability which support the enablement of the EMP goals. In addition, many AMI vendors with commercially available solutions have invested significant time and resources in research and development and developed extensive partnerships with other manufacturers to develop interoperability within their solutions. As a result, AMI solutions provide for such interoperability and allow access for numerous products, such as air conditioners, thermostats, refrigerators, washers, dryers and other appliances. In addition, due to the increasing capabilities of these communications infrastructures, information from installations that include combined heat and power, micro-grids and photovoltaic/battery installations can be readily obtained and used to provide efficient and necessary energy to the grid. These positive impacts can provide significant benefits to New Jersey's citizens and support the numerous goals identified in the EMP.

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[2] http://energy.gov/sites/prod/files/2014/08/f18/SmartGrid-SystemReport2014.pdf
[3] http://smartgridcc.org/smart-grid-environmental-and-economic-benefits-report/

It is important to note that these benefits are not theoretical. They are, in many cases, being provided today throughout the United States and overseas. For example: AMI infrastructure developed in Texas, Oklahoma, California and Ontario currently provides similar benefits, in addition to time varying rate designs, demand response programs and innovative market programs to meet customer needs and state goals.

RECO respectfully suggests that the focus of the Dynamic Pricing and Metering goal include not only dynamic pricing consideration as regards smart meters but consideration of all of the functionality and benefits that AMI infrastructure and meters will provide.

RECO also recommends consideration of AMI infrastructure as an element the Draft Update as regards resiliency and emergency preparedness. As noted above, AMI benefits include the improved energy infrastructure resiliency and emergency preparedness referenced in the Draft Update. Among the lessons from Superstorm Sandy is the importance of specific outage information which can be shared with customers and used to efficiently provide for necessary repair. AMI will provide such information thereby significantly enhancing customer communication, and improving both efficiency and time expended for repair.

RECO has developed a plan for a cost effective AMI deployment that includes the above referenced AMI capabilities, as well as, detailed benefits and costs for its service territory. We will submit that plan to the Board at a future date. RECO believes that the expertise it has developed around AMI through significant benchmarking and research, and in concert with deployment by RECO's parent, Orange and Rockland Utilities, Inc. in New York, provides for a unique opportunity to implement state of the art AMI system that will enable the tangible advancement of EMP goals.

Thank you for the opportunity to provide these comments.

Respectfully submitted,

Edwin J. Ortiz
Vice President
Customer Service

Comments of William P. O'Hearn
November 2015 Update of New Jersey Energy Master Plan
December 4, 2015

My name is William O'Hearn, and I am a private citizen and Clean Energy Business Advocate who has been following the renewable energy industry for the last 8 years. The following comments are an update to the testimony I presented on the 2011 Energy Master Plan (EMP) on August 11, 2015 in Newark, N.J.

During those hearings in August, the great majority of speakers called for a return to the goals that were included in the 2008 EMP, especially the 30% renewable energy goal by 2020, which was lowered to 22.5% by 2021 in the 2011 EMP. They also consistently called for a much greater emphasis on encouraging and expanding the use of solar, wind and energy conservation as the means of meeting these goals.

I was disappointed to see that the November 2015 Update to the EMP retains the 22.5% goal, and that it continues to focus on consumer pricing as the number one goal of the EMP. Energy rates are important, but as we are facing the global threat of climate change, they are not the top priority for energy policy. If they were, we would all be happily burning coal, because that is the cheapest fuel for generating electricity, if you don't factor in the external costs of air pollution, sea rise, mercury, mountaintop removal, etc.

The top energy priority for New Jersey and the rest of the planet is the rapid reduction of CO_2 and methane emissions to avoid catastrophic climate change. That is why the November Update's conclusion that New Jersey is doing fine because of its reliance on nuclear and natural gas is fundamentally flawed—natural gas is cleaner than coal, but it is not "clean" energy, and as a fossil fuel it should not be a major player in our long-term plans.

I recommend the following additions to the November Update of the EMP:

- Stop fighting the EPA's Clean Power Plan (CPP) issued this fall, and look for ways to comply with or exceed the CPP's requirement that NJ cut its emissions by 26% below 2012 levels by 2030.
- Rejoin the Regional Greenhouse Gas Initiative, or RGGI, to take advantage of this cap and trade system that would allow us to work with other northeastern states that never left the program.
- Call for the extension of the federal Investment Tax Credit (ITC) to maintain the growth of the state's solar industry through 2017 and beyond.
- Benchmark against other states that are outside the PJM system, like New York, Connecticut and Massachusetts. Note that California made a recent commitment to cut emissions by 50% by 2030.
- Push aggressively on offshore wind energy like the Fishermen's Energy project off of Atlantic City.

- Make a commitment to close the last coal-powered plants in New Jersey, as other states have done.
- Include a section on the projected costs of climate change if emissions continue at the current rate, including sea level rise, greater storm intensity, increased droughts, effects on fishing industry, etc.
- Add more information on how lower costs of solar, wind and storage are driving new technologies including community solar, demand response, and time-of-use pricing, and how utility business models are changing to reflect this.

Other Steps to Add to the Plan (carried over from August 2015 testimony)

CONSERVATION.

- Streamline the Clean Energy Program to make our energy conservation and efficiency dollars go farther.
- Develop aggressive incentives for energy audits and retrofits of existing buildings.
- Increase outreach and marketing efforts to encourage the public to conserve energy.

TRANSPORTATION.

- Add land use planning policies and practices that strive to minimize auto miles traveled.
- Increase support for mass transit to take more cars off the road.
- Support the expansion of electric cars and solar carports/recharging stations; encourage fleets (postal service, delivery companies, rental cars, taxis, etc.) to go electric.

RENEWABLES

- Establish one common set of standards and permits to cut the time wasted on conflicting and confusing local rules and permits for installing solar and other renewable energy.
- Call for the re-establishment of the PACE homeowner solar financing program in New Jersey.
- Add solar panels, and small wind if appropriate, to the governor's mansion and state capitol, as other states have already done.
- Note that coal, nuclear and natural gas plants use almost half (more than agriculture) of all the freshwater in the U.S. for cooling, another powerful reason for pursuing clean energy.

In short, as I stated in my August testimony, the November Update should call for moving away from fossil fuels, and investing heavily in renewables and generating local green jobs, or we risk losing our leadership position in the country and missing a huge economic opportunity. In Paris this month, countries from across the globe are being challenged to increase their commitments to emission reductions, and New Jersey should do no less.

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December 4, 2015

<u>VIA ELECTRONIC MAIL</u>
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New Jersey Board of Public Utilities
44 South Clinton Avenue
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<u>EMPUpdate@bpu.state.nj.us</u>

Re: **<u>JCP&L Comments on 2011 Energy Master Plan Update (November 2015)</u>**

Dear Secretary Asbury:

This firm represents Jersey Central Power & Light Company ("***JCP&L***" or the "***Company***") in providing the following comments with respect to the above-referenced matter. The New Jersey Board of Public Utilities (the "***Board***") has requested comments for the 2011 New Jersey Energy Master Plan ("***2011 EMP***") Update issued on November 20, 2015 (the "***EMP Update***"). JCP&L appreciates this opportunity to provide these comments for consideration in the important process of finalizing the EMP Update, which will continue to set the direction for New Jersey's energy policy over the remainder of, and beyond, the current decade.

As reflected in the Company's initial comments of August 24, 2015, the Company continues to support the high-level goals of the 2011 EMP, which as updated, continues, generally, to strike an appropriate balance among the sometimes competing objectives of lower costs, economic growth, energy security and diversity, and environmental protection. The Company also continues to agree with the 2011 EMP's objective that renewable or energy efficiency programs or projects should be expected to produce net benefits that will outweigh the costs of the initiatives and continues to support the use of properly structured cost-effectiveness tests to help New Jersey achieve the 2011 EMP objective of reducing costs to utility customers while maintaining a strong delivery infrastructure. This objective continues to be stressed in the EMP Update. Sustainable and affordable programs that do not impose excessive or unnecessary costs on utility customers remain essential to successfully pursuing and achieving the objectives of the State's clean energy initiatives.

The Company appreciates that the EMP Update recognizes the benefits to the State and its citizens contributed by the State's regulated utilities through their "significant capital infusion" and "investment that strengthens and enhances the State's economy and critical infrastructure" as well as the criticality of stable and viable utility companies to the State's economic life and vitality. EMP Update at pp. 1-2. This recognition provides a useful contextual backdrop for appreciating the appropriate balance in the EMP Update between its emphasis on the value of renewable energy, energy efficiency, conservation and other new energy technologies, on the one hand, and the need for successful and synergistic integration of these tools and objectives with the utilities' infrastructure; particularly the electric grid, on the other hand. The Board is to be complimented for its efforts to strike this balance, which recognizes the vital importance of appropriately supporting, strengthening and enhancing the essential foundation provided by such utility infrastructure, which provides the circulatory system for the State's energy lifeblood.[1]

JCP&L is encouraged by the tone and substance of the EMP Update, which reflects thoughtful consideration of available energy-related data, valuable stakeholder input, and actual and practical experience since 2011, and which serves to bring the State's energy master plan up-to-date with a somewhat sharper focus on the evolving energy future. In this spirit of appreciation and encouragement, JCP&L wishes to provide some additional comments regarding specific aspects of the EMP Update, which it hopes will provide the Board with helpful insights for further honing the focus and direction of the EMP Update. The Company will follow the EMP Update goal and/or Plan for Action orientation in providing its comments.

Drive Down the Cost of Energy For All Customers

JCP&L believes that it is appropriate for the EMP Update to recognize that there is and will be a need to build significant new transmission infrastructure (EMP Update at p. 3). The EMP Update clearly highlights the Board's support for the enhancement and expansion of the natural

[1] For example, the introduction to the EMP Update appropriately states that: "[e]conomic growth depends on abundant affordable supplies of energy" and that the "generation and delivery of reliable and safe energy is a key element of a healthy economy." The introduction also underscores the critical mission of the State's public utilities in managing and maintaining their infrastructure, which keeps the electric, gas, water and data flowing..." These and other parts of the EMP Update provide the necessary perspective for promoting dynamic, yet prudent and holistic, energy innovation in a manner that does not undercut the economies and efficiencies of existing utility systems that are themselves adapting to the changing energy landscape described by the EMP Update.

gas transmission and distribution system (*id.*) as an element of reducing energy costs. With respect to electric transmission system upgrades and expansion, while the EMP Update recognizes that upgrades and expansion will be necessary, the EMP Update, primarily, tends to view these electric transmission system needs in juxtaposition to (i) potentially failing to build sufficient new, clean, in-state generation[2] and (ii) the need to protect critical utility infrastructure.[3] The Company believes that the EMP Update should also recognize that while there are, indeed, cost implications related to upgrading and building new electric transmission infrastructure, notwithstanding the jurisdictional realities, by providing access to a wider mix of generation resources (including where it will offset in-state generation needs), reducing congestion and enhancing reliability of delivery in the long run, the upgrading and building of new electric transmission infrastructure can also contribute to the goal of driving down the overall cost of energy for all customers. The Company believes that State policy as reflected by the EMP Update should more overtly recognize the need for, and the contribution of, upgrading and expanding the electric transmission system in order to meet the 2011 EMP energy cost

[2] *See*, for example, EMP Update at p. 20 ("Absent the development of new, in-state power generation, New Jersey will need to rely on more transmission to meet local electricity deficiencies").

[3] *See*, for example, EMP Update at p. 46 ("In the electric power sector, system vulnerabilities and critical infrastructure protection at the regional grid level are addressed as part of PJM's annual Regional Transmission Expansion Plan (RTEP) process. Through the RTEP process, load forecasts, studies, and computer models test the transmission system for vulnerabilities and weaknesses against mandatory North American Electric Reliability Corporation (NERC) reliability standards").

objectives through the use of the Board's siting authority and appropriate monitoring and support in the context of PJM and FERC processes and proceedings.[4]

Promote a Diverse Portfolio of New, Clean, In-State Generation

JCP&L notes that the EMP Update encourages the expansion of Combined Heat and Power ("***CHP***") systems of all forms including district energy systems and intends for the State to "keep a focus on expanding use of CHP by reducing financial, regulatory and technical barriers and identifying opportunities for new entries." EMP Update at 19. The EMP Update recommends that the Board initiate a stakeholder process to address these barriers so as to "increase the development of [distributed generation "***DG***"] with a focus on CHP… [including] revisions to the CHP and fuel cell incentives to promote local resiliency." *Id.* JCP&L appreciates the Board's stakeholder approach to these issues, which the Company encouraged in its earlier comments. However, JCP&L suggests that the recommendation also more specifically

[4] *See*, for example, EMP Update at pp. 17-18 ("The State will continue its evaluation and analysis of New Jersey's electric capacity needs as well as other issues associated with transmission planning to identify areas of congestion, inordinately high electricity prices, and the proper functioning of the power market. This includes enhancing the capacity of the natural gas pipeline infrastructure to take advantage of low natural gas prices to assist in lowering electricity prices"). Compare with the New Jersey Utility Association ("***NJUA***") Comment Letter dated August `3, 2015 at p. 4 ("NJUA respectfully recommends that the EMP Update convey support for the expansion of both electric and natural gas transmission. Improvements to both systems will improve economic efficiency and lower costs to consumers. The expansion and reinforcement of the electric transmission system will enhance reliability, reduce congestion, and lower prices. Electric transmission development is primarily driven by regional planning processes managed by PJM Interconnection and its stakeholders, but the State can support transmission by expediting siting and permitting processes, and supporting appropriate equity returns and incentives to attract capital investment").

refer to the need for the stakeholder process to include careful analysis of claimed electric system benefits, which are often generally touted but seldom specifically quantified in order to transparently identify the true cost to consumers from DG.[5]

Reward Energy Efficiency and Energy Conservation/Reduce Peak Demand

JCP&L notes that while the EMP Update appropriately recommends the evaluation of New Jersey's Clean Energy Program ("***NJCEP***") programs through a stakeholder process, it also recommends that the Board "evaluate ways to enhance the effectiveness of the [electric distribution company "***EDC***"] and [gas distribution company "***GDC***"] programs and consider whether it should shift energy efficiency programs to the [administration of] the EDCs and GDCs." EMP Update at 34. In this regard, as stated in the Company's earlier comments, JCP&L continues to believe that the current model for delivery of energy efficiency programs that allows for both utility-initiated and State-administered programs can continue to function effectively. The Company sees no energy efficiency programmatic advantage to be gained by implementing such a shift in responsibilities. The need to evaluate such a proposed change in responsibilities before evaluating and assessing the costs, benefits and opportunities created by the shift (effective in 2016) to a single NJCEP market manager and program administrator,

[5] In this regard, the Company continues to recommend that the EMP Update should specifically emphasize the need for DG proponents to provide information and data regarding, among other things, cost savings, electric system benefits, levels of DG penetration and projected load growth, without which decision-making regarding rate design and inter-, and intra-, customer rate class impacts cannot be reasonably made.

appears premature and counter-intuitive.[6]

Regarding energy efficiency building codes, JCP&L appreciates the important work that has been undertaken in terms of adding aggressive energy efficiency requirements to building codes, as discussed in the EMP Update (at pp. 38-39), and, looks forward to such codes being adopted thereby stimulating increased market penetration for energy efficiency and conservation technology and approaches, which, in turn, may lessen the need for NJCEP energy efficiency program subsidies.

Finally, while the EMP Update does not recommend any changes to the goal of monitoring energy storage developments (EMP Update at p. 42), JCP&L suggests that the EMP Update could be strengthened with respect to this goal by indicating encouragement and support (including appropriate cost-recovery) for the use of energy storage technologies by the State's public utilities in and through energy storage system pilot programs on a stand-alone basis or as a component of reliability and resiliency enhancement projects.

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[6] The Company has previously indicated that it believes State-administered statewide energy efficiency programs provide a consistent, efficient channel to market programs to consumers. In addition to reducing delivery costs, these programs help to minimize consumer confusion regarding program offerings across utility boundaries. Further, because there are surplus funds from Societal Benefits Charge ("*SBC*") collections, statewide programs may be expanded without additional costs to utility customers. The Company suggests that the EMP Update defer revaluation of this issue until the more significant change in NJCEP administration is evaluated and assessed in due course.

Maintain Support for the Renewable Energy Portfolio Standard

While JCP&L commends the Board for its efforts and progress relative to this goal, the Company notes that the EMP Update contains a Board recommendation regarding "significant solar development volatility" (EMP Update at pp. 23-24), which includes possible actions to limit "EDC sales of SRECs to recover costs...." *Id.* The Company believes that even encouraging the consideration of this limitation is misguided insofar as these sales offset the cost to ratepayers of the EDC SREC-based financing and solar loan programs.[7] Given the history of subsidies and the sensitivities regarding cost-shifting between net-metering participants and non-participants (as discussed in earlier JCP&L comments and those of NJUA), the Company does not think it necessary or appropriate to encourage consideration of this particular limitation at ratepayers' expense even in the face of significant solar development volatility. The Company believes that the turning to the consideration of market-based stimuli, incentives or limitations in the event of such volatility would be far more appropriate for purposes of supporting what is fast becoming a growing and maturing solar industry.[8]

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[7] This very point is recognized further in the EMP Update at p. 26 ("...some of [the EDCs'] costs are returned to the ratepayer based on SREC revenues").

[8] JCP&L also notes that the EMP Update finds that net-metered solar generation, which is on-site, does not consume the "vast amounts of open space measured in square miles" that may be required by "large scale grid-supply projects." EMP Update at p. 6. JCP&L wishes to share with the Board the observation that certain net-metered solar PV projects can also use large amounts of open space, which has engendered degrees of public opposition underscoring that there may be a tipping point at which compatible State goals (*i.e.*, renewable energy, whether or not net-metered, and open space) can become competing ones.

Improve Energy Infrastructure Resiliency and Emergency Preparedness and Response

The Company is pleased with the overall direction taken by the EMP Update in addressing the additional challenges that have arisen since 2011 related to resiliency and emergency response in light of Hurricane Irene, the October 2011 Snowstorm and the 2012 Superstorm Sandy. JCP&L believes, as it had suggested in earlier comments, that it was appropriate for the EMP Update to cite and discuss the Board's, Board Staff and the EDCs' hard work in addressing the unprecedented storm experience and the strategic issues flowing from that experience. This work was reflected in Board Staff's reports, the resulting Board Orders and the EDCs' implementation of Board Ordered recommendations resulting from thoughtful consideration of the many issues and multitude of variables. The Company also appreciates the very appropriate and necessary linkage, clearly articulated in the EMP Update, between (i) the State's continued support for utility "infrastructure hardening or preparedness applications" and (ii) fiscal prudence. EMP Update at p. 48. In JCP&L's view, this kind of balancing, while sometimes requiring more thoughtfulness and analysis, most often leads to reasonable and practical approaches using proven technologies and methodologies at reasonable costs yielding practical and satisfactory solutions.

In conjunction with the goal of protecting the State's critical energy infrastructure, the Company observes that the EMP Update recommends that the "BPU should also continue to work with the EDCs on the new vegetation management pilot program currently underway to reduce tree-related outages. EMP Update at p. 48. While JCP&L supports the Board's efforts following the 2011 and 2012 catastrophic storms to facilitate new and enhanced approaches to EDC vegetation management throughout the State, the Company believes that it would be more productive and better serve the Board's long term objectives with respect to this facet of utility operations to focus this EMP Update recommendation on the implementation of the Board's recently adopted vegetation management regulations (at N.J.A.C. 14:5-9.1 *et seq.*). These regulations codified certain reliability-related vegetation management techniques, goals and reporting obligations developed collaboratively in the aftermath of the 2011-12 storm experiences. The Company thinks that this change in the focus of the recommendation, rather than to specifically focus on a now-completed pilot program, would strengthen the focus and objective of the recommendation.

The Company also supports the attention in the EMP Update to improving and enhancing the "EDC Smart Grid and Distribution Automation Plans" with its clear emphasis on the importance of understanding the associated costs and benefits (including with respect to smart or advanced metering, which was not the focus of earlier EDC plans). EMP Update at pp. 49-50. JCP&L's concern with the EMP Update in this regard, however, is that the recommendation to "require the four EDCs to update their SG/DA plans" (*id.*) may not effectively convey the magnitude of the required effort and may create unreasonable expectations regarding the timing and results of such efforts. JCP&L suggests that the EMP Update more specifically recommend the inclusion of an EDC working group approach as part of the SG/DA plan update process in order to reasonably establish common terminology and issue definition as well as to develop a common appreciation for the current and developing state-of-the-art and a realistic assessment of customer needs and wants and the associated costs, risks and benefits. JCP&L also suggests that the EMP Update should provide policy support for the use of innovative cost recovery mechanisms to facilitate implementation of programs to be undertaken under this goal.[9]

The EMP Update also states a goal to "increase the use of microgrid technologies and applications" for distributed energy resources ("***DER***") "to improve the grid's resiliency and reliability in the event of a major storm." EMP Update at pp.50-51. The interest in microgrids in New Jersey has certainly increased in the aftermath of Hurricane Irene and Superstorm Sandy and the EMP Update seeks to encourage that interest in the context of improved grid resiliency. In JCP&L's view, while the subject and use of microgrids deserves serious attention as part of the State's energy master plan, there is also a need for a clearer understanding of the grid-related issues and challenges that arise from expanded use of microgrid technologies including those related to parallel operations, interconnection and the concomitant safety, engineering, operational and communications-related considerations that accompany wider implementation. Indeed, from a policy perspective attention is needed to distinguish and understand the

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[9] In its earlier comments, JCP&L also more generally encouraged the Board to consider alternative ratemaking mechanisms to accelerate utility infrastructure investment, including mechanisms that provide more contemporaneous return of and more competitive return on utility capital investments because they are necessary to attract the capital necessary to fund the types of initiatives set forth in the 2011 EMP. JCP&L continues to encourage the Board to consider more specific support for the consideration of these types of mechanisms in the context of furthering the goals of the EMP Update.

differences between certain types of critical infrastructure resilience and grid resiliency. While JCP&L is encouraged that the EMP Update recommends that the State continue its work with various stakeholders, including utilities, the EMP Update recommendation appears only to apply to the specific context of the identification, design and implementation of "Town Center DER microgrids to power critical facilities and services across the State." EMP Update at p. 51. While the Board Staff's "Microgrid Report," once finalized, may shed further light in a broader context, it is not clear that it will because the reference to Staff's report in the EMP Update only refers to same Town Center DER context. Although the Town Center DER concept is an important one that deserves specific attention, JCP&L believes that the broader topic of DER, including microgrids, and utility integration, more generally, including with respect to utility ownership and operation, deserves specific recognition in the EMP Update and further attention in the form of Board-led collaborative generic processes.

Conclusion

In closing, the Company reiterates that it appreciates the opportunity to comment on the EMP Update, which continues to strike a reasonable balance and provide a sound foundation for achieving the State's goals for energy, the environment and the economy over the remainder of the decade. The Company hopes that its comments and suggestions will assist the Board in finalizing the EMP Update. If there any questions regarding these comments and associated ideas and concepts, JCP&L would be very pleased to address them.

Respectfully submitted,

Jersey Central Power & Light Company

By: ______________________
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From: Amy Hansen
Sent: Friday, December 04, 2015 4:48 PM
To: EMPupdate
Cc: Alison Mitchell; Tom Gilbert; Michele Byers; Hunter, Benjamin; Amy Hansen
Subject: Comments re: Updated 2011 Energy Master Plan
Attachments: Howarth_2015_methane_emissions_summary.pdf; Howarth-2014-Energy_Science_&_Engineering.pdf

December 4, 2015

New Jersey Board of Public Utilities
44 S. Clinton Avenue Trenton, NJ 08625

Re: Updated 2011 Energy Master Plan

To Whom It May Concern:

New Jersey Conservation Foundation (NJ Conservation) appreciates the opportunity to comment on the updated 2011 Energy Master Plan. NJ Conservation protects natural areas and farmland through land acquisition and stewardship, promotes strong land use policies and forges partnerships to help safeguard clean water and other natural resources.

For over 50 years, we have saved more than 130,000 acres of land from sprawl development. Today, we face major challenges from poorly-planned energy infrastructure – the new sprawl. Pipelines, transmission lines and transfer stations now threaten thousands of acres of land across our state. While we recognize the critical importance of ensuring reliable energy to New Jersey consumers and businesses, we are concerned about the lack of comprehensive planning for energy infrastructure to determine public need, to assess impacts to our environment and communities, and to evaluate the best alternatives for meeting the state's energy needs.

New Jersey's energy policy has the potential to support clean, renewable sources of energy that can help address global warming while decreasing threats posed by fossil fuel infrastructure to our ecologically important and sensitive lands and natural resources, provide critical benefits such as clean drinking water, tourism and recreational opportunities, wildlife habitat and historical, scenic and cultural landscapes.

Unfortunately, the updated 2011 Energy Master Plan (EMP) takes us in the wrong direction, and continues to rely too heavily on natural gas, a fossil fuel that contributes to climate change, and requires costly and damaging long-lived infrastructure projects, such as the numerous new pipelines proposed throughout the state.

This EMP includes a section that purports to address the challenges to New Jersey and our energy infrastructure from Superstorm Sandy. But by continuing a strong dependence on natural gas, which emits both carbon dioxide and methane, a powerful greenhouse gas, we are not addressing the climate change challenges that are clearly seen in more frequently occurring dangerous storms and sea level rise. Greenhouse gas emissions increased by 14% in 2014, largely due to emissions from gas-fired electric plants. This figure does not include methane emissions.

We would like to draw your attention to some important findings regarding the high level of methane emissions produced by shale gas and conventional natural gas. Please see attached a two-page summary of the research entitled "Howarth 2015 Methane Emissions Summary" as well as an article published by Howarth et al. in Energy and Science & Engineering.

The EMP states: "New Jersey enjoys some of the lowest emission rates from power plants in the country… According to the U.S. Energy Information Administration (EIA), New Jersey's sulfur dioxide (SO2) emissions are amongst the three lowest states in the nation and nitrogen oxide and carbon dioxide (CO_2) emissions are amongst the six lowest states in the nation. In comparison to the 13-state PJM regional transmission region, New Jersey ranks, by far, the lowest of all…"

While the state should be commended on low emission rates for several pollutants, the EIA does not list methane emissions from shale gas and conventional natural gas, which is a large and potentially dangerous oversight. Methane is a very potent greenhouse gas that directly impacts global warming.

The attached Howarth 2015 Methane Emissions Summary, states: "In the first comprehensive study of greenhouse gas emissions from shale gas, Howarth, Santoro, and Ingraffea concluded that due to methane, shale gas has a larger climate impact than either coal or oil (April 2011 in *Climatic Change Letters*). They also called for new measurements to better assess these methane emissions. An explosion of new information has been published since then, reviewed by Howarth in 2014 in *Energy Science & Engineering* and again in 2015 in *Energy & Emission Control Technologies*. This flyer summarizes those updates. *The most recent research supports the 2011 analysis, and indicates greenhouse gas emissions from shale – dominated by methane -- are large and will have disastrous consequences for the Earth's climate."*

A recent study by the Union of Concerned Scientists identified New Jersey as one of a number of states that is over-reliant on natural gas, putting ratepayers and the environment at risk.

Another article at http://www.reportingclimatescience.com/news-stories/article/study-methane-means-natural-gas-no-better-than-coal-and-oil.html highlights the findings by Howarth: "Using these new, best available data and a 20-year time period for comparing the warming potential of methane to carbon dioxide, the conclusion stands that both shale gas and conventional natural gas have a larger GHG than do coal or oil, for any possible use of natural gas and particularly for the primary uses of residential and commercial heating. The 20-year time period is appropriate because of the urgent need to reduce methane emissions over the coming 15–35 years…"

Due to the information provided above regarding carbon dioxide and methane emissions, and the threat posed to New Jersey's open space, farmland and communities by proposed gas pipelines, NJ Conservation strongly opposes the EMP's goal (page 20) of promoting the expansion of gas pipelines. We strongly support amendments to the EMP that would require comprehensive planning for energy infrastructure that would include a determination of public need, a thorough assessment of environmental and community impacts, and an evaluation of the best alternatives to meet the state's energy needs in a cost-effective manner while reducing harmful greenhouse gas emissions.

The updated EMP dwells too much on the price of New Jersey's power relative to other states and ignores the expensive impacts of an over reliance on natural gas. These impacts include ratepayer funding of unnecessary infrastructure and the hazards of continued climate change. New Jersey's energy plans should be rapidly adjusted to decrease natural gas usage and infrastructure development.

We do strongly support the EMP in its goal of rewarding energy efficiency and conservation and reducing peak demand, proven success measures that reduce our need for new power plants and dirty fuel and its infrastructure. The EMP states: "The BPU is exploring ways to increase the efficiency programs that gas users and distributers are taking advantage of in order to achieve a reduction in energy bills and usage…" and correctly asserts "…more efficient in-state electricity generation, as well as increased energy efficiency, including increases in the building energy codes and appliance standards, can continue to stabilize and potentially lower NJ's electricity costs…" (page 17).

New Jersey can do more, and we urge an increase in the State's energy reduction goals, to, at minimum, 30% by 2030, and more going forward. The American Council for an Energy Efficient Economy (ACEEE) released its 2015 scorecard on statewide energy efficiency and unfortunately, New Jersey weighs in at 21, losing ground since 2014 when we were number 19. We are a state of innovators, and with a focused effort, we can decrease our energy usage and work our way up the scorecard toward Massachusetts and California, which are ranked first and second respectively.

ACEEE highlights where New Jersey can improve, stating: "the existing utility business model does not encourage investment in energy efficiency. As other states in the region significantly ramp up programs year after year, to keep up with its peer states New Jersey will need to ramp up energy savings levels and adopt and enforce long-term energy efficiency targets. Offering performance incentives to utilities and protecting ratepayer dollars collected for clean energy programs from being transferred into the general fund could also help increase the impact of New Jersey's energy efficiency programs. (http://aceee.org/sites/default/files/pdf/state-sheet/2015/new-jersey.pdf)

We support the EMP's goals of increased usage of Combined Heat and Power (CHP) and distributed generation from solar and wind. It is important that the State is working to increase participation levels for CHP – this is a critical priority that will help us reach our goal of a substantial reduction in energy use.

Due to reasons stated above, we strongly oppose the goal of expanding the usage and infrastructure for natural gas. The EMP includes a goal of 70% of our energy being provided by clean energy. As noted above, natural gas is most certainly not a clean source of fuel and should not be considered part of meeting this target.

NJ Conservation asks the State to go further, and set a goal of 80% of our energy coming from solar, wind and truly clean renewables by 2050, which includes the use of battery storage. We strongly disagree with the EMP when it advises changing the definition of clean energy to include natural gas. Again, it is of utmost importance to immediately recognize and address the harm caused by carbon dioxide and methane emissions from natural gas production and use.

We support the goals in the 2011 EMP to increase education and outreach to residents and industry in order to achieve energy reduction and renewable energy goals.

According to the National Association of State Utility Consumer Advocates, with or without the Clean Power Plan, states that pursue renewables and energy efficiency will see smaller increases in total electric-system costs through 2030 than they would with any other investment strategy.

Energy efficiency and conservation provide numerous benefits while also saving land and critical natural resources. NJ Conservation applauds the EMP's clear recommendation that preserved farmland and open space remains protected in perpetuity. It is also critical that additional farmland, forests and open space be permanently preserved, rather than being developed for energy infrastructure.

The EMP does not support the use of ratepayer subsidies to turn productive farmland into industrial solar facilities. This is excellent policy, and should be expanded to include forests as we should not be using green fields or forests for development, not even renewable energy development, given the numerous more appropriate locations available in our state. The importance of preserving more natural carbon sinks such as forests and other greenfields to combat global warming will only increase in the future.

New Jersey needs to re-enroll in the Regional Greenhouse Gas Initiative (RGGI), as all our residents would benefit. New Jersey Conservation worked with the legislature when the Global Warming Response Act was drafted to ensure that ten percent of the Initiative's carbon auction proceeds would fund forest stewardship plans and salt marsh restoration for carbon sequestration purposes. The auction proceeds would be a boon for these and other programs that could help create robust and innovative partnerships with the other RGGI states to achieve aggressive energy reduction and decreased greenhouse gas emission goals.

We urge you to revise the EMP in order to help us catalyze a rapid transition to truly clean renewable sources of energy and greater energy efficiency, and away from further reliance on fossil fuels such as natural gas that pose significant threats to our land, water, climate and communities.

Thank you again for the opportunity to provide comments on New Jersey's energy policy. Please contact us at 908-234-1225 with any questions or concerns.

Sincerely,

Tom Gilbert, Campaign Director for Energy, Climate and Natural Resources
Amy Hansen, Policy Analyst
New Jersey Conservation Foundation

Amy Hansen
Policy Analyst
New Jersey Conservation Foundation
Bamboo Brook
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Some commonly asked questions:

Aren't carbon dioxide emissions less for natural gas than for coal? Yes, substantially so. But methane emissions are far greater from natural gas, particularly from shale gas. When methane is included, total greenhouse gas emissions are greater from natural gas than from coal, particularly when analyzed on a 20-year period following emission.

I've heard that methane is 21-times more powerful as a greenhouse gas than is carbon dioxide. Is that true? No, that is based on a 20-year old report of the Intergovernmental Panel on Climate Change (IPCC) in 1995. The IPCC now states that methane is more than 100-times more powerful for the first decade after emission, 86-times over a 20-year period, and 34-times over 100 years. The shorter time periods are the most appropriate to use, given the urgency of slowing global warming over the coming 10 to 20 years, and when considering the idea of a "bridge fuel."

Why are the EPA methane estimates so low? The EPA states that methane is 25-fold more powerful than carbon dioxide, considering only the 100-year time scale and using information from an older IPCC report from 2007 rather than the most recent 2013 one. Further, their estimates of methane emission rates are much too low and are not supported by the most recent peer-reviewed science.

Can regulation reduce methane emissions to an acceptable level? Methane emissions come from many sources, from the well site to delivery through pipelines to final customers. Many of these remain poorly characterized. Reducing emissions is expensive, particularly from pipelines and storage tanks that are frequently 50 to 100 years old, and enforcement of regulations is difficult. Society is better off investing in renewable energy infrastructure.

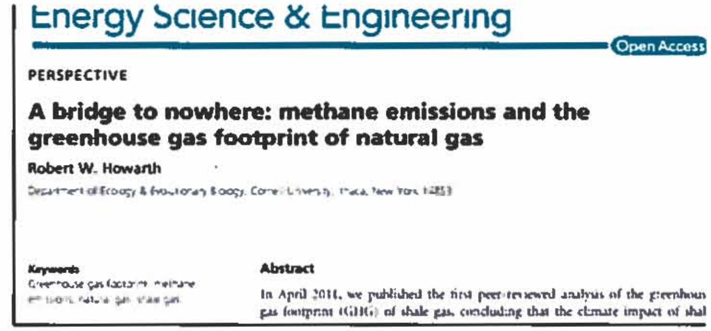
If natural gas is not a bridge fuel, should we burn coal instead? No. The high levels of carbon dioxide emitted from using coal have a lasting influence on the atmosphere and climate for many centuries. It is past time to move away from all fossil fuels, and embrace the renewable energy technologies of the 21st Century.

Aren't cows more important as a source of methane than the natural gas industry? Globally, animal agriculture and the natural gas industry are comparable sources of methane. In the US, the natural gas industry is the far greater source, but both sources should be reduced.

For more information see:
http://www.eeb.cornell.edu/howarth/energy_and_environment.php

Cornell University

August 21, 2015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PERSPECTIVE

A bridge to nowhere: methane emissions and the greenhouse gas footprint of natural gas

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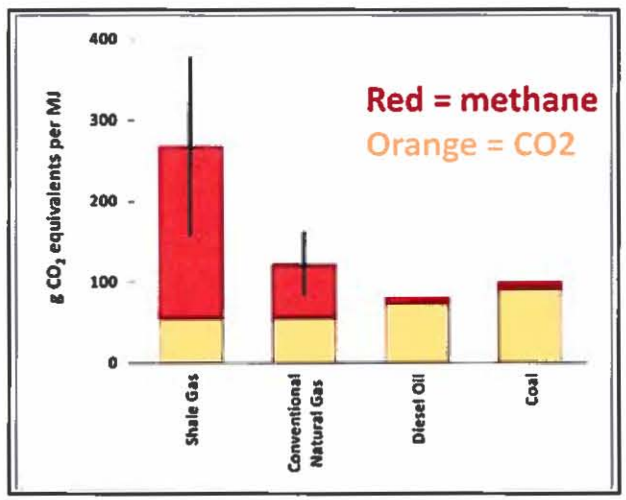
Keywords
Greenhouse gas footprint, methane emissions, natural gas, shale gas

Abstract
In April 2011, we published the first peer-reviewed analysis of the greenhous gas footprint (GHG) of shale gas, concluding that the climate impact of shal

Natural gas is widely promoted as a "bridge fuel" that allows continued use of fossil fuels while reducing greenhouse gas emissions compared to oil or coal. Increasingly since 2009, natural gas has come from shale gas, as conventional sources of gas have been depleted. Today, over 40% of US natural gas comes from shale. Is shale gas really a bridge fuel?

In the first comprehensive study of greenhouse gas emissions from shale gas, Howarth, Santoro, and Ingraffea concluded that due to methane shale gas has a larger climate impact than either coal or oil (April 2011 in *Climatic Change Letters*). They also called for new measurements to better assess these methane emissions. An explosion of new information has been published since then, reviewed by Howarth in 2014 in *Energy Science & Engineering* and again in 2015 in *Energy & Emission Control Technologies*. This flyer summarizes those updates.

The most recent research supports the 2011 analysis, and indicates greenhouse gas emissions from shale – dominated by methane -- are large and will have disastrous consequences for the Earth's climate.

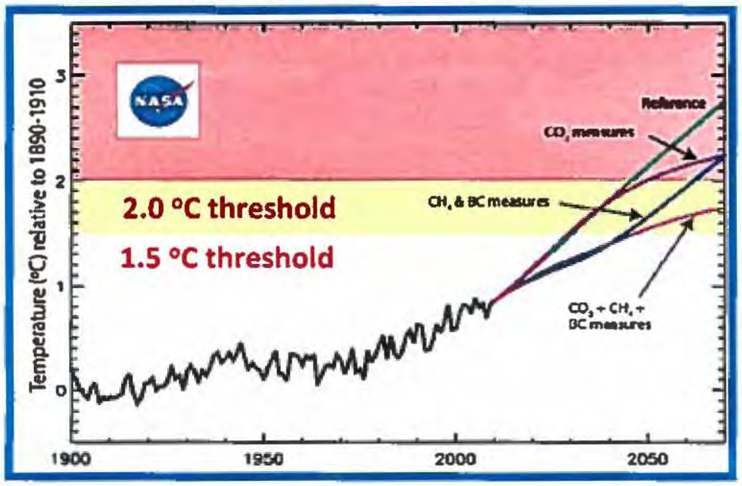


Source: Howarth (2015) *Energy & Emission Control Technologies*

Methane compared to carbon dioxide over a 20-year time period following emission to the atmosphere. Both direct emissions of carbon dioxide and methane emissions expressed as carbon dioxide equivalents are shown. For each fuel, the best estimate for methane emission is used. The vertical bars illustrate the the most probable range of values for shale gas and conventional natural gas.

Carbon dioxide vs. methane:

- **Methane is greater than 100 times more powerful as an agent of global warming, while both gases are in the atmosphere.**
- **The atmosphere contains more carbon dioxide than methane, making it the larger driver behind global warming, but methane is also important: 1.66 watts per square meter for carbon dioxide vs. 1.0 for methane.**
- **The effective residence times of the two gases in the atmosphere are very different: a little over a decade for methane and hundreds of years for carbon dioxide.**
- **Because of its long residence time, reductions in carbon dioxide emissions can only slowly change the atmospheric concentration, leading to a lag of many decades before global warming is slowed.**
- **With methane's short residence time, emissions reductions lead to almost immediate reductions in atmospheric concentrations; thus, reducing methane emissions now will significantly slow the rate of global warming almost immediately.**



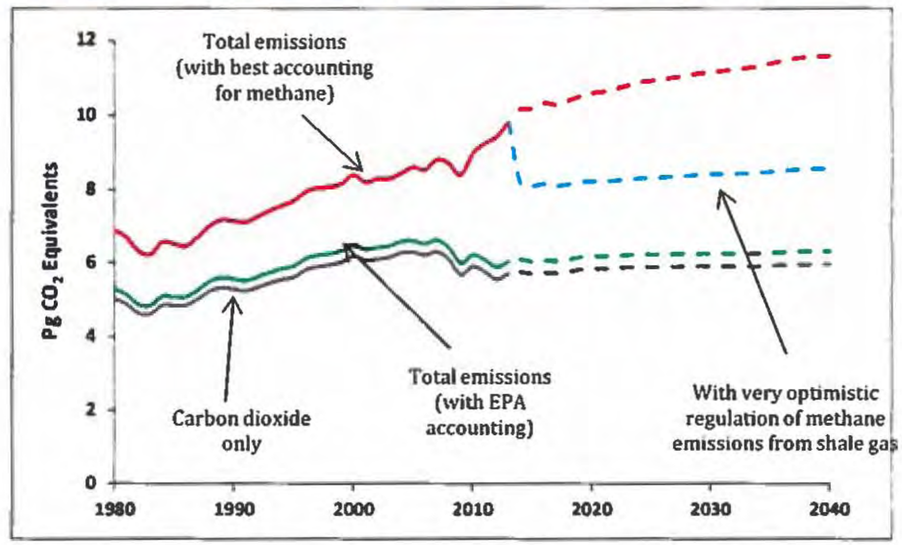
Source: Shindell and others (2012). *Science* 335: 183-189.

Within the next 15 years, the Earth will warm to very dangerous levels, doubling the total increase in the average temperature that has occurred since the start of the industrial revolution to now. Tipping points in the climate system may kick in and lead to runaway global warming. Only by reducing methane emissions and emissions of soot (black carbon, or BC) can society slow the rate of warming and buy precious time while moving aggressively toward a renewable energy economy. The natural gas industry is by far the largest source of methane emissions in the United States.

How much methane does the natural gas industry emit?

Methane emissions are better known now than in 2011, but estimates remain uncertain. The best current estimate of emissions from conventional natural gas comes from an analysis of over 12,000 monitoring observations taken before large-scale shale gas development began (Miller et al., 2003, *Proceedings of the National Academy of Sciences*). The best estimate of emissions from shale gas comes from satellite observations of increases in methane in the atmosphere before and after shale gas development began (Schneising et al., 2014, *Earth's Future*). Most other observations are for short periods of time, making it difficult to relate to gas production over the lifetime of a well. The lowest estimates -- part of a study promoted by the Environmental Defense Fund in coordination with industry -- have been called into question because of sensor failures with the instrumentation used (Howard, 2015, *Energy Science & Engineering*).

Carbon dioxide emissions from fossil fuels in the US have fallen since 2007 due largely to economic recession but also to switching from coal to shale gas. However, when methane emissions are properly included, total fossil-fuel greenhouse gas emissions have increased rapidly in recent years. In 2013, methane emissions contributed 40% of all fossil-fuel emissions in the US. The EPA accounting approach hugely underestimates the importance of methane emissions.



Total greenhouse gas emissions from fossil fuel use in the US through 2013 and predicted future trends based on US Dept. of Energy predictions for energy use. Grey line is for just carbon dioxide emissions. Red line includes methane. Green line shows total emissions as estimated by the US EPA, which greatly underestimates methane emissions and their importance. Blue line indicates a possible future scenario of reducing methane emissions from shale gas, with very optimistic assumptions on the ability of regulations to cut emissions. Source: Howarth (2015) *Energy and Emission Control Technologies*.

Energy Science & Engineering

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PERSPECTIVE

A bridge to nowhere: methane emissions and the greenhouse gas footprint of natural gas

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Funding Information
Funding was provided by Cornell University, the Park Foundation, and the Wallace Global Fund.

Received: 4 March 2014; Revised: 18 April 2014; Accepted: 22 April 2014

***Energy Science and Engineering* 2014; 2(2): 47–60**

doi: 10.1002/ese3.35

Abstract

In April 2011, we published the first peer-reviewed analysis of the greenhouse gas footprint (GHG) of shale gas, concluding that the climate impact of shale gas may be worse than that of other fossil fuels such as coal and oil because of methane emissions. We noted the poor quality of publicly available data to support our analysis and called for further research. Our paper spurred a large increase in research and analysis, including several new studies that have better measured methane emissions from natural gas systems. Here, I review this new research in the context of our 2011 paper and the fifth assessment from the Intergovernmental Panel on Climate Change released in 2013. The best data available now indicate that our estimates of methane emission from both shale gas and conventional natural gas were relatively robust. Using these new, best available data and a 20-year time period for comparing the warming potential of methane to carbon dioxide, the conclusion stands that both shale gas and conventional natural gas have a larger GHG than do coal or oil, for any possible use of natural gas and particularly for the primary uses of residential and commercial heating. The 20-year time period is appropriate because of the urgent need to reduce methane emissions over the coming 15–35 years.

Introduction

Natural gas is often promoted as a bridge fuel that will allow society to continue to use fossil energy over the coming decades while emitting fewer greenhouse gases than from using other fossil fuels such as coal and oil. While it is true that less carbon dioxide is emitted per unit energy released when burning natural gas compared to coal or oil, natural gas is composed largely of methane, which itself is an extremely potent greenhouse gas. Methane is far more effective at trapping heat in the atmosphere than is carbon dioxide, and so even small rates of methane emission can have a large influence on the greenhouse gas footprints (GHGs) of natural gas use.

Increasingly in the United States, conventional sources of natural gas are being depleted, and shale gas (natural gas obtained from shale formations using high-volume hydraulic fracturing and precision horizontal drilling) is rapidly growing in importance: shale gas contributed only 3% of United States natural gas production in 2005, rising to 35% by 2012 and predicted to grow to almost 50% by 2035 [1]. The gas held in tight sandstone formations is another form of unconventional gas, also increasingly obtained through high-volume hydraulic fracturing and is growing in importance. In 2012, gas extracted from shale and tight-sands combined made up 60% of total natural gas production, and this is predicted to increase to 70% by 2035 [1]. To date, shale gas has been almost entirely a North American phenomenon, and largely a U.S. one, but many expect shale gas to grow in global importance as well.

In 2009, I and two colleagues at Cornell University, Renee Santoro and Tony Ingraffea, took on as a research challenge the determination of the GHG of unconventional gas, particularly shale gas, including emissions of methane. At that time, there were no papers in the peer-reviewed literature on this topic, and there were relatively few papers even on the contribution of methane to the GHG of conventional natural gas [2–4]. At the end of 2009, the U.S. Environmental Protection Agency (EPA) still did not distinguish between conventional gas and shale gas, and they estimated methane emissions for the natural gas industry using emission factors from a 1996 study conducted jointly with the industry [5]; shale gas is not mentioned in that report, which is not surprising since significant shale gas production only started in the first decade of the 2000s.

We began giving public lectures on our analysis in March 2010, and these attracted media attention. One of our points was that it seemed likely that complete life cycle methane emissions from shale gas (from well development and hydraulic fracturing through delivery of gas to consumers) were greater than from conventional natural gas. Another preliminary conclusion was that the EPA methane emission estimates (as they were reported in 2009 and before, based on [5]) seemed at least two- to three-fold too low. In response to public attention from our lectures, the EPA began to reanalyze their methane emissions [6], and in late 2010, EPA began to release updated and far higher estimates of methane emissions from the natural gas production segment [7]. In April 2011, we published our first paper on the role of methane in the GHG of shale gas [8]. We concluded that (1) the amount and quality of available data on methane emissions from the natural gas industry were poor; (2) methane emissions from shale gas were likely 50% greater than from conventional natural gas; and (3) these methane emissions contributed significantly to a large GHG for both shale gas and conventional gas, particularly when analyzed over the timescale of 20-years following emission. At this shorter timescale – which is highly relevant to the concept of natural gas as a bridge or transitional fuel over the next two to three decades – shale gas appeared to have the largest greenhouse warming consequences of any fossil fuel (Fig. 1). Because our conclusion ran counter to U.S. national energy policy and had large implications for climate change, and because the underlying data were limited and of poor quality, we stressed the urgent need for better data on methane emissions from natural gas systems. This need has since been amplified by the Inspector General of the EPA [9].

Our paper received immense media coverage, as evidenced by Time Magazine naming two of the authors

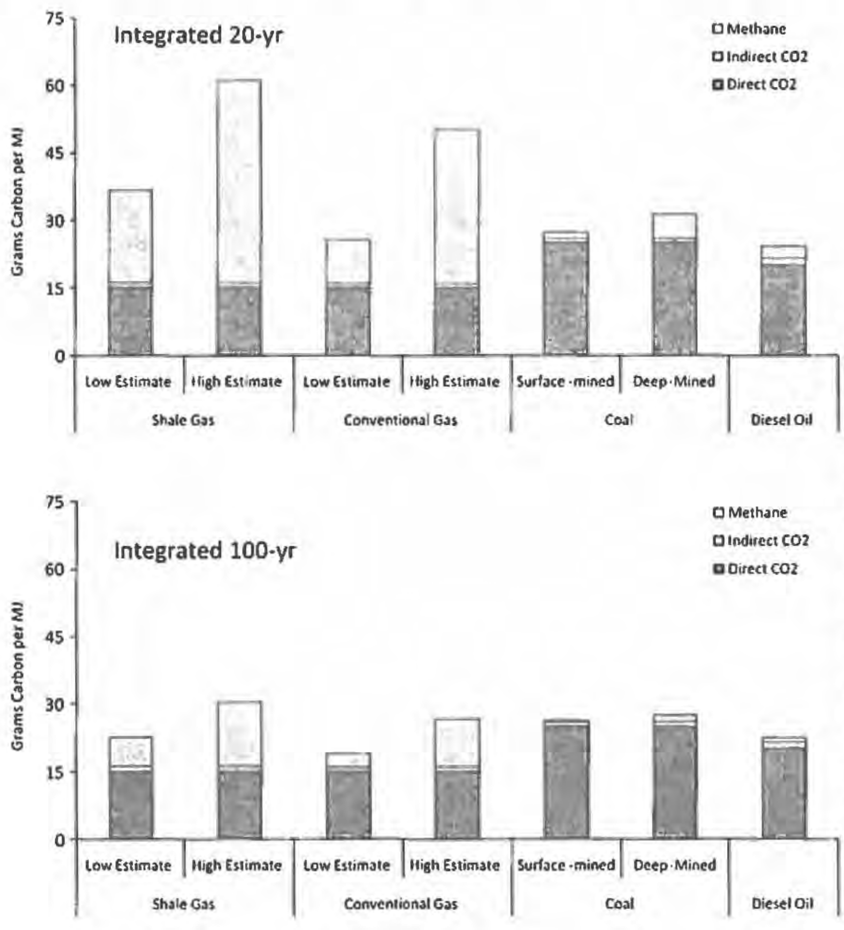

Figure 1. Comparison of the greenhouse gas footprint of shale gas, conventional natural gas, coal, and oil to generate a given quantity of heat. Two timescales for analyzing the relative warming of methane and carbon dioxide are considered: an integrated 20-year period (top) and an integrated 100-year period (bottom). For both shale gas and conventional natural gas, estimates are shown for the low- and high-end methane emission estimates from Howarth et al. [8]. For coal, estimates are given for surface-mined and deep-mined coal, since methane emissions are greater for deeper mines. Blue bars show the direct emissions of carbon dioxide during combustion of the fuels; the small red bars show the indirect carbon dioxide emissions associated with developing and using the fuels; and the magenta bars show methane emissions converted to g C of carbon dioxide equivalents using period-appropriate global warming potentials. Adapted from [8]

(Howarth and Ingraffea) "People who Mattered" to the global news in the December 2011 Person of the Year Issue [10]. The nine months after our paper was published saw a flurry of other papers on the same topic, a huge increase in the rate of publication on the topic of methane and natural gas compared to prior years and decades. While some of these offered support for our analysis, most did not and were either directly critical of our work, or without referring to our analysis reached conclusions more favorable to shale gas as a bridge fuel. Few of these papers published in the 9 months after our April 2011 paper provided new data; many simply offered different interpretations of previously presented information (as is reviewed briefly below). However, in 2012 and 2013 many new studies were published with major new insights and sources of data. In this paper, I briefly review the work on methane and natural gas published between April 2011 and February 2014, concentrating on those studies that have produced new primary data.

There are four components that are central to evaluating the role of methane in the GHG footprint of natural gas: (1) the amount of carbon dioxide that is directly emitted as the fuel is burned and indirectly emitted to obtain and use the fuel; (2) the rate of methane emission from the natural gas system (often expressed as a fraction of the lifetime production of the gas well, normalized to the amount of methane in the gas produced); (3) the global warming potential (GWP) of methane, which is the relative effect of methane compared to carbon dioxide in terms of its warming of the global climate system and is a function of the time frame considered after the emission of the methane; and (4) the efficiency of use of natural gas in the energy system. The GHG is then determined as:

$$\text{GHG footprint} = [CO_2\text{emissions} + (\text{GWP} \times \text{methane emissions})]/\text{efficiency}$$

There is widespread consensus on the magnitude of the direct emissions of carbon dioxide, and the indirect emissions of carbon dioxide used to obtain and use natural gas (for example, in building and maintaining pipelines, drilling and hydraulically fracturing wells, and compressing gas), while uncertain, are also relatively small [8]. In this paper, I separately consider each of the other three factors (methane emissions, GWP, and efficiency of use) in the context of our April 2011 paper [8] and the subsequent literature.

How Much Methane is Emitted by Natural Gas Systems?

We used a full life cycle analysis in our April 2011 paper, estimating the amount of methane emitted to the atmosphere as a percentage of the lifetime production of a gas well (normalized to the methane content of the natural gas), including venting and leakages at the well site but also during storage, processing, and delivery to customers. For conventional natural gas, we estimated a range of methane emissions from 1.7% to 6% (mean = 3.8%), and for shale gas a range of 3.6% to 7.9% (mean = 5.8%) [8]. We attributed the larger emissions from shale gas to venting of methane at the time that wells are completed, during the flowback period after high-volume hydraulic fracturing, consistent with the findings of the EPA 2010 report [7]. We assumed all other emissions were the same for conventional and shale gas. We estimated that downstream emissions (emissions during storage, long-distance transport of gas in high-pressure pipelines, and distribution to local customers) were 1.4–3.6% (mean = 2.5%) of the lifetime production of a well, and that the upstream emissions (at the well site and for gas processing) were in the range of 0.3–2.4% (mean = 1.4%) for conventional gas and 2.2–4.3% (mean = 3.3%) for shale gas (Table 1).

Table 1. Full life cycle-based methane emission estimates, expressed as a percentage of total methane produced in natural gas systems, separated by upstream emissions for conventional gas, upstream emissions for unconventional gas including shale gas, and downstream emissions for all natural gas. Studies are listed chronologically, and our April 2011 study is boldfaced.

	Upstream conventional gas	Upstream unconventional gas	Downstream
EPA 1996 [5]	0.2%		0.9%
Hayhoe et al. [2]	1.4		2.5
Jamarillo et al. [4]	0.2		0.9
Howarth et al. [8]	**1.4**	**3.3**	**2.5**
EPA [11]	1.6	3.0	0.9
Ventakesh et al. [12]	1.8		0.4
Jiang et al. [13]		2.0	0.4
Stephenson et al. [14]	0.4	0.6	0.07
Hultman et al. [15]	1.3	2.8	0.9
Burnham et al. [16]	2.0	1.3	0.6
Cathles et al. [17]	0.9	0.9	0.7

Total emissions are the sum of the upstream and downstream emissions. Studies are listed chronologically by time of publication. Dashes indicate no values provided. The full derivation of the estimates shown here is provided elsewhere [18, 19].

Although there were no prior papers on methane emissions from shale gas when our paper was published, we can compare our estimates for conventional natural gas with earlier literature (Table 1). Our mean estimates for both upstream and downstream emissions were identical to the "best estimate" of Hayhoe et al. [2], although that paper presented a wider range of estimates for both upstream and downstream. It is important to note that we used several newer sources of information not available to Hayhoe et al. [2], making the agreement all the more remarkable. The Howarth et al. [8] estimates were substantially higher than the emission factors used by the EPA through 2009 based on the 1996 joint EPA-industry study [5], which were only 1.1% for total emissions, 0.2% for upstream emissions, and 0.9% for downstream emissions. In the only other peer-reviewed paper on life cycle methane emissions from conventional gas published in the decade or two before our paper, Jamarillo et al. [4] relied on these same EPA emission factors, although new data on downstream emissions had already shown these emission factors to be too low [3].

Through late 2010 and the first half of 2011, the EPA provided a series of updates on their methane emission factors from the natural gas industry, giving estimates for shale gas for the first time as well as substantially increasing their estimates for conventional natural gas. These are discussed in detail by us elsewhere [18, 19]. Note that the EPA did not and still has not updated their estimates for downstream emissions, still using a value of 0.9% from a 1996 study [5]. For upstream emissions, the revised EPA estimates gave emission factors of 1.6% (an increase from their earlier value of 0.2%) for conventional natural gas and 3.0% for shale gas [18, 19]. Note that the EPA estimates for upstream emissions presented in 2011 [11] were 14% higher than ours for conventional gas and 10% lower than ours for shale gas. Total emissions were more divergent, due to the large difference in downstream emission estimates (Table 1).

In addition to the revised EPA emission factors, many other papers presented life cycle assessments of methane emissions from shale gas, conventional gas, or both in the immediate 9 months after April 2011 (Table 1). We and others have critiqued these publications in detail elsewhere [18–20]. Here, I will emphasize four crucial points:

1. For the upstream emissions in Table 1, all studies relied on the same type of poorly documented and highly uncertain information. These poor-quality data led us in Howarth et al. [8] to call for better measurements on methane fluxes, conducted by independent scientists. Several such studies have been published in the past 2 years, as is discussed further below, and these provide a more robust approach for estimating methane emissions.
2. At least some of the differences among values in Table 1 are due more to different assumptions about the lifetime production of a shale gas well than to differences in emissions per well [18, 20]. Note that the upstream life cycle emissions are scaled to the lifetime production of a well (normalized to the methane content of the gas produced for the estimates given in Table 1), and this was very uncertain in 2011 since shale gas development is such a new phenomenon [21]. A subsequent detailed analysis by the U.S. Geological Survey has demonstrated that the mean lifetime production of unconventional gas wells is in fact lower than any of papers in Table 1 assumed [22], meaning that upstream shale gas emissions per production of the well from all of the studies should be higher, in some cases substantially so [18, 20].
3. The downstream emissions in Table 1 are particularly uncertain, as highlighted by both Hayhoe et al. [2] and Howarth et al. [8]. Note that all of the other papers listed in Table 1 base their downstream emissions on the EPA emission factors from 1996 [5], and none are higher than those EPA estimates, even though a 2005 paper in *Nature* demonstrated higher levels of emission from long-distance pipelines in Europe [3]. Several of the papers in Table 1 have downstream emissions that are lower than the 1996 EPA values, as they are focused on electric power plants and assume that these plants are drawing on gas lines that have lower emissions than the average, which would include highly leaky low-pressure urban distribution lines [12–14, 16]. Some recent papers have noted a high incidence of leaks in natural gas distribution systems in two U.S. east coast cities [23, 24], but these new studies have yet placed an emission flux estimate on these leaks. Another study demonstrated very high methane emissions from fossil fuel sources in Los Angeles but could not distinguish between downstream natural gas emissions and other sources [25]. Given the age of gas pipelines and distribution systems in the United States, it should come as no surprise that leakage may be high [8, 18, 19]. Half of the high-pressure pipelines in the United States are older than 50 years [18], and parts of the distribution systems in many northeastern cities consist of cast-iron pipes laid down a century ago [24].
4. While one of the papers in Table 1 by Cathles and his colleagues [17], characterized our methane emission estimates as too high and "at odds with previous studies," that in fact is not the case. As noted above, both our downstream and upstream estimates for conventional gas are in excellent agreement with one of the few previous peer-reviewed studies [2]. Furthermore, our upstream emissions are in good agreement with the majority of the papers published in 9 months after

ours: for conventional gas, our mean estimate of 1.4% compares with the mean for all the other studies in Table 1 of 1.33%; if we exclude the very low estimate from Stephenson et al. [14], which was based on an analysis of what the gas industry is capable of doing rather than on any new measurements, and also the relatively low estimate from Cathles et al. [17], which was based on the assumption that the gas industry would not vent gas for economic and safety issues (see critique of this in [18]), the mean of the other four studies is 1.7, or almost twice as high as the Cathles et al. [17] estimate and 20% higher than our estimate. For shale gas, again excluding Stephenson et al. [14] and Cathles et al. [17] as well as our estimate, the other four studies in Table 1 have a mean estimate of 2.3, a value 2.5-fold greater than that from Cathles et al. [17] and 30% less than our mean estimate. From this perspective, the estimates of Cathles et al. [17] appear to be greater outliers than are ours.

Since 2012, many new papers have produced additional primary data (Fig. 2). Two of these found very high upstream methane emission rates from unconventional gas fields (relative to gross methane production), 4% for a tight-sands field in Colorado [26] and 9% for a shale gas field in Utah [27], while another found emissions from a shale gas field in Pennsylvania to be broadly consistent with the emission factors we had published in our 2011 paper [28]. All three of these studies inferred rates from atmospheric data that integrated a large number of wells at the basin scale. The new Utah data [27] are much higher than any of the estimates previously published for upstream emissions from unconventional gas fields (Fig. 2), while the measurement for the Colorado tight-sands field [26] overlaps with our high-end estimate for upstream unconventional gas emissions in Howarth et al. [8]. The Utah and Colorado studies may not be representative of the typical methane emissions for the entire United States, in part, because they focused on regions where they expected high methane fluxes based on recent declines in air quality. But I agree with the conclusion of Brandt and his colleagues [29] that the "bottom-up" estimation approaches that we and all the other papers in Table 1 employed are inherently likely to lead to underestimates, in part, because some components of the natural gas system are not included. As one example, the recent Pennsylvania study, which quantified fluxes from discrete locations on the ground by mapping methane plumes from an airplane, found very high emissions from many wells that were still being drilled, had not yet reached the shale formation, and had not yet been hydraulically fractured [28]. These wells represented only 1% of the wells in the area but were responsible for 6–9% of the regional methane flux from all sources. One explanation is that the drill rigs encountered pockets of shallower gas and released this to the atmosphere. We, the EPA, and all of the papers in Table 1 had assumed little or no methane emissions from wells during this drilling phase.

Allen and colleagues [30] published a comprehensive study in 2013 of upstream emissions for both conventional and unconventional gas wells for several regions in the United States, using the same basic bottom-up approach as the joint EPA-industry study of 1996 used [5]. As with that earlier effort, this new study relied heavily on industry cooperation, and was funded largely by industry with coordination provided by the Environmental Defense Fund. For the United States as a whole at the

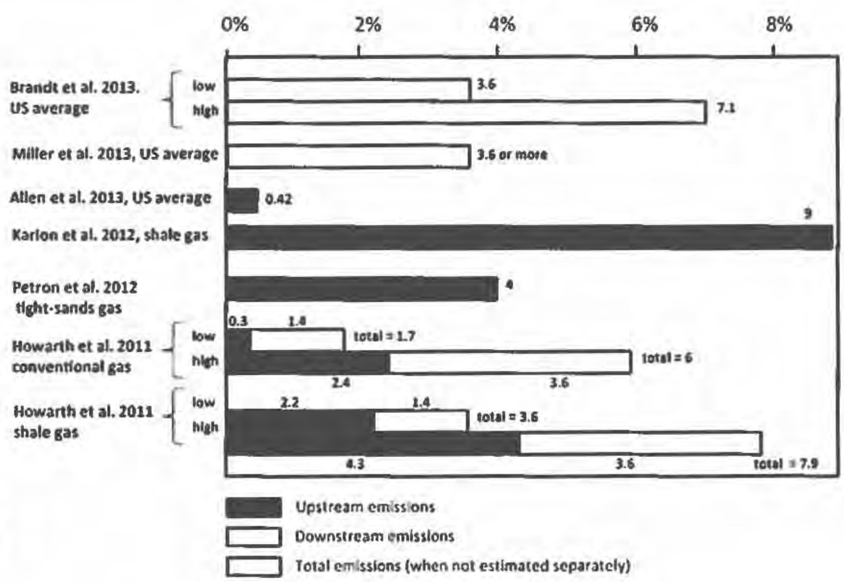

Figure 2. Comparison of recent new data on methane emissions compared to the estimates published in Howarth et al. [8]. Some of the new data are for upstream emissions, while others give only averages for natural gas systems in the United States. No new measurements for downstream emissions alone have been published since 2005 [8, 26, 27, 29, 30, 32].

time of their study, Allen et al. [30] concluded that upstream methane emissions were only 0.42% of the natural gas production by the wells (Fig. 2), a value at the low end of those seen in Table 1. Using the low-end estimates, "best-case" scenarios for upstream emissions from Howarth et al. [8] and the mix of shale gas and conventional gas produced in the United States in 2012, I estimate the U.S. national best-case emission rate would be 0.5%, or similar to that observed by Allen and colleagues. It should not be surprising that their study, in relying on industry access to their sampling points, ended up in fact measuring the best possible performance by industry.

In 2013, the EPA reduced their emission estimates for the oil and gas industry, essentially halving their upstream emissions for average natural gas systems from 1.8% to 0.88% for the year 2009 (with the mix of conventional and unconventional gas for that year) from what they had reported in 2011 and 2012; the EPA estimate for downstream emissions remained at 0.9%, giving a total national emission estimate of 1.8%. EPA took this action to decrease their emission factors for upstream emissions despite the publication in 2012 of the methane emissions from a Colorado field [26] and oral presentations at the American Geophysical Union meeting in December 2012 of the results subsequently published by Karion and colleagues [27] and Caulton and colleagues [28], all of which would have suggested higher emissions, perhaps spectacularly so. As is discussed by Karion et al. [27], the decrease in the upstream methane emissions by EPA in 2013 was driven by a non-peer-reviewed industry report [31] which argued that emissions from liquid unloading and during refracturing of unconventional wells were far lower than used in the EPA [11] assessment. At least in part in response to these changes by EPA, the Inspector General for the EPA concluded that the agency needs improvements in their approach to estimating emissions from the natural gas industry [9].

An important paper published late in 2013 [32] indicates the EPA made a mistake in reducing their emission estimates earlier in the year. In this analysis, the most comprehensive study to date of methane sources in the United States, Miller and colleagues used atmospheric methane monitoring data for 2007 and 2008 – 7710 observations from airplanes and 4984 from towers from across North America – together with an inverse model to assess total methane emissions nationally from all sources. They concluded that rather than reducing methane emission terms between their 2011 and 2013 inventories, EPA should have increased anthropogenic methane emission estimates, particularly for the oil and gas industry and for animal agriculture operations. They stated that methane emissions from the United States oil and gas industry are very likely two-fold greater or more than indicated by the factors EPA released in 2013 [32]. This suggests that total methane emissions from the natural gas industry were at least 3.6% in 2007 and 2008 (Fig. 2).

In early 2014, Brandt and his colleagues [29] reviewed the technical literature over the past 20 years on methane emissions from natural gas systems. They concluded that "official inventories consistently underestimate actual methane emissions," but also suggested that the very high estimates from the top–down studies in Utah and Colorado [26, 27] "are unlikely to be representative of typical [natural gas] system leakage rates." In the supplemental materials for their paper, Brandt et al. [29] state that methane emissions in the United States from the natural gas industry are probably greater than the 1.8% assumed by the EPA by an additional 1.8–5.4%, implying an average rate between 3.6% and 7.1% (mean = 5.4%) [33] (Fig. 2).

This recent literature suggests to me that the emission estimates we published in Howarth et al. [8] are surprisingly robust, particularly for conventional natural gas (Fig. 2). The results from two of the recent top–down studies [26, 27] indicate our estimates for unconventional gas may have been too low. Partly in response to our work and their own reanalysis of methane emissions from shale gas wells, EPA has now promulgated new regulations that will as of January 2015 reduce methane emissions at the time of well completions, requiring capture and use of the gas instead in most cases. Some wells are exempt, and the regulation does not apply to venting of methane from oil wells, including shale oil wells, which often have associated gas. Nonetheless, the regulations are an important step in the right direction, and will certainly help, if they can be adequately enforced. Even still, though, results such as those from the Pennsylvania flyover showing high rates of methane emission during the drilling phase of some shale gas wells [28] suggest that methane emissions from shale gas may remain at levels higher than from conventional natural gas.

The GWP of Methane

While methane is far more effective as a greenhouse gas than carbon dioxide, methane has an atmospheric lifetime of only 12 years or so, while carbon dioxide has an effective influence on atmospheric chemistry for a century or longer [34]. The time frame over which we compare the two gases is therefore critical, with methane becoming relatively less important than carbon dioxide as the timescale increases. Of the major papers on methane and the GHG for conventional natural gas published before our analysis for shale gas, one modeled the relative radiative forcing by methane compared to carbon dioxide continuously over a 100-year time period following emission [2], and two used the global warming approach (GWP) which compares how much larger the integrated global warming from a given mass of methane is over a specified period of time compared to the same mass of carbon dioxide. Of the two that used the GWP approach, one showed both 20-year and 100-year GWP analyses [3] while another used only a 100-year GWP time frame [4]. Both used GWP values from the Intergovernmental Panel on Climate Change (IPCC) synthesis report from 1996 [35], the most reliable estimates at the time their papers were published. In subsequent reports from the IPCC in 2007 [36] and 2013 [34] and in a paper in *Science* by workers at the NASA Goddard Space Institute [37], these GWP values have been substantially increased, in part, to account for the indirect effects of methane on other radiatively active substances in the atmosphere such as ozone (Table 2).

In Howarth et al. [8], we used the GWP approach and closely followed the work of Lelieveld and colleagues [3] in presenting both integrated 20 and 100 year periods, and in giving equal credence and interpretation to both timescales. We upgraded the approach by using the most recently published values for GWP at that time [37].

Table 2. Comparison of the timescales considered in comparing the global warming consequences of methane and carbon dioxide

Publication	Timescale considered	20-year GWP	100-year GWP
IPCC [35]	**20 and 100 years**	**56**	**21**
Hayhoe et al. [2]	0 100 years	NA	NA
Lelieveld et al. [3]	20 and 100 years	56	21
Jamarillo et al. [4]	100 years		21
IPCC [36]	**20 and 100 years**	**72**	**25**
Shindell et al. [37]	**20 and 100 years**	**105**	**33**
Howarth et al. [8]	20 and 100 years	105	33
Hughes [20]	20 and 100 years	105	33
Venkatesh et al. [12]	100 years		25
Jiang et al. [13]	100 years		25
Wigley [38]	0 100 years	NA	NA
Stephenson et al. [14]	100 years		25
Hultman et al. [15]	20 and 100 years	72, 105	25, 44
Skone et al. [39]	100 years		25
Burnham et al. [16]	100 years		25
Cathles et al. [17]	100 years		25
Alvarez et al. [40]	0 100 years	NA	NA
IPCC [34]	**10, 20, and 100 years**	**86**	**34**
Brandt et al. [29]	100 years		25

Studies are listed chronologically by time of publication. Values for the global warming potentials at 20 and 100 years given, when used in the studies. NA stands for not applicable and is shown when studies did not use the global warming potential approach. Dashes are shown for studies that did not consider the 20-year GWP. Studies that are bolded provided primary estimates on global warming potentials, while other studies are consumers of this information.

These more recent GWP values increased the relative warming of methane compared to carbon dioxide by 1.9-fold for the 20-year time period (GWP of 105 vs. 56) and by 1.6-fold for the 100-year time period (GWP of 33 vs. 21; Table 2). Our conclusion was that for the 20-year time period, shale gas had a larger GHG than coal or oil even at our low-end estimates for methane emission (Fig. 1); conventional gas also had a larger GHG than coal or oil at our mean or high-end methane emission estimates, but not at the very low-end range for methane emission (the best-case, low-emission scenario). At the 100-year timescale, the influence of methane was much diminished, yet at our high-end methane emissions, the GHG of both shale gas and conventional gas still exceeded that of coal and oil (Fig. 1).

Of nine new reports on methane and natural gas published in 9 months after our April 2011 paper [8], six only considered the 100-year time frame for GWP, two used both a 20- and 100-year time frame, and one used a continuous modeling of radiative forcing over the 0–100 time period (Table 2). Of the six papers that only examined the 100-year time frame, all used the lower GWP value of 25 from the 2007 IPCC report rather than the higher value of 33 published by Shindell and colleagues in 2009 that we had used; this higher value better accounts for the indirect effects of methane on global warming. Many of these six papers implied that the IPCC dictated a focus on the 100-year time period, which is simply not the case: the IPCC report from 2007 [36] presented both 20- and 100-year GWP values for methane. And two of these six papers criticized our inclusion of the 20-year time period as inappropriate [14, 17]. I strongly disagree with this criticism. In the time since April 2011 I have come increasingly to believe that it is essential to consider the role of methane on timescales that are much shorter than 100 years, in part, due to new science on methane and global warming presented since then [34, 41, 42], briefly summarized below.

The most recent synthesis report from the IPCC in 2013 on the physical science basis of global warming highlights the role of methane in global warming at multiple timescales, using GWP values for 10 years in addition to 20 and 100 years (GWP of 108, 86, and 34, respectively) in their analysis [34]. The report states that "there is no scientific argument for selecting 100 years compared with other choices," and that "the choice of time horizon .... depends on the relative weight assigned to the effects at different times" [34]. The IPCC further concludes that at the 10-year timescale, the current global release of methane from all anthropogenic sources exceeds (slightly) all anthropogenic carbon dioxide emissions as agents of global warming; that is, methane emissions are more important (slightly) than carbon dioxide emissions for driving the current rate of global warming. At the 20-year timescale, total global emissions of methane are equivalent to over 80% of global carbon dioxide emissions. And at the 100-year timescale, current global methane emissions are equivalent to slightly less than 30% of carbon dioxide emissions [34] (Fig. 3).

This difference in the time sensitivity of the climate system to methane and carbon dioxide is critical, and not widely appreciated by the policy community and even some climate scientists. While some note how the long-term momentum of the climate system is driven by carbon dioxide [15], the climate system is far more immediately responsive to changes in methane (and other short-lived radiatively active materials in the atmosphere, such as black carbon) [41]. The model published in 2012 by Shindell and colleagues [41] and adopted by the United Nations [42] predicts that unless emissions of methane and black carbon are reduced immediately, the Earth's average surface temperature will warm by 1.5°C by about 2030 and by 2.0°C by 2045 to 2050 whether or not carbon dioxide emissions are reduced. Reducing methane and black carbon emissions, even if carbon dioxide is not controlled, would significantly slow the rate of global warming and postpone reaching the 1.5°C and 2.0°C marks by 15–20 years. Controlling carbon dioxide as well as methane and black carbon emissions further slows the rate of global warming after 2045, through at least 2070 [41, 42] (Fig. 4).

Why should we care about this warming over the next few decades? At temperatures of 1.5–2.0°C above the 1890–1910 baseline, the risk of a fundamental change in the Earth's climate system becomes much greater [41–43], possibly leading to runaway feedbacks and even more global warming. Such a result would dwarf any possible benefit from reductions in carbon dioxide emissions over the next few decades (e.g., switching from coal to natural gas, which does reduce carbon dioxide but also increases methane emissions). One of many mechanisms for such catastrophic change is the melting of methane clathrates in the oceans or melting of permafrost in the Arctic. Hansen and his colleagues [43, 44] have suggested that warming of the Earth by 1.8°C may trigger a large and rapid increase in the release of such methane. While there is a wide range in both the magnitude and timing of projected carbon release from thawing permafrost and melting clathrates in the literature [45], warming consistently leads to greater release. This release can in turn cause a feedback of accelerated global warming [46].

To state the converse of the argument: the influence of today's emissions on global warming 200 or 300 years into the future will largely reflect carbon dioxide, and not

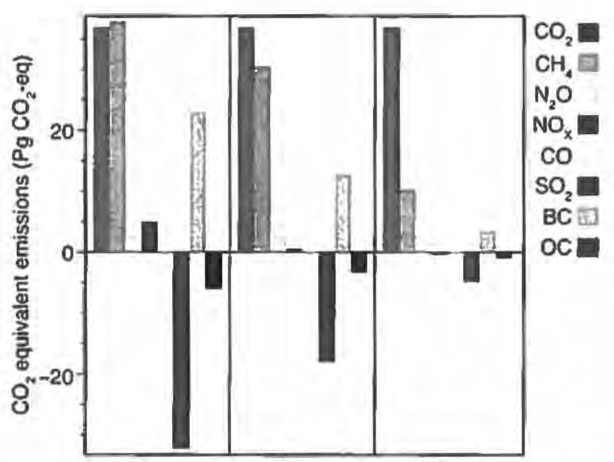

Figure 3. Current global greenhouse gas emissions, as estimated by the IPCC [34], weighted for three different global warming potentials and expressed as carbon dioxide equivalents. At the 10-year time frame, global methane emissions expressed as carbon dioxide equivalents actually exceed the carbon dioxide emissions. Adapted from [34].

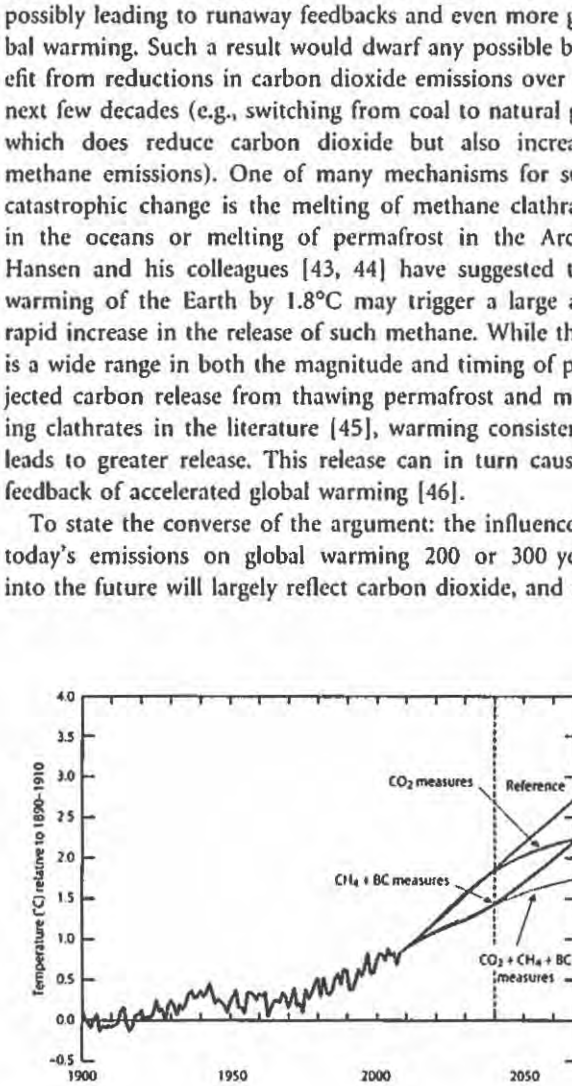

Figure 4. Observed global mean temperature from 1900 to 2009 and projected future temperature under four scenarios, relative to the mean temperature from 1890 to 1910. The scenarios include the IPCC [36] reference, reducing carbon dioxide emissions but not other greenhouse gases ("CO_2 measures"), controlling methane, and black carbon emissions but not carbon dioxide ("CH_4 + BC measures"), and reducing emissions of carbon dioxide, methane, and black carbon ("CO_2 + CH_4 + BC measures"). An increase in the temperature to 1.5–2.0°C above the 1890–1910 baseline (illustrated by the yellow bar) poses risk of passing a tipping point and moving the Earth into an alternate state for the climate system. The lower bound of this danger zone, 1.5° warming, is predicted to occur by 2030 unless stringent controls on methane and black carbon emissions are initiated immediately. Controlling methane and black carbon shows more immediate results than controlling carbon dioxide emissions, although controlling all greenhouse gas emissions is essential to keeping the planet in a safe operating space for humanity. Adapted from [42].

methane, unless the emissions of methane lead to tipping points and a fundamental change in the climate system. And that could happen as early as within the next two to three decades.

An increasing body of science is developing rapidly that emphasizes the need to consider methane's influence over the decadal timescale, and the need to reduce methane emissions. Unfortunately, some recent guidance for life cycle assessments specify only the 100-year time frame [47, 48], and the EPA in 2014 still uses the GWP values from the IPCC 1996 assessment and only considers the 100-year time period when assessing methane emissions [49]. In doing so, they underestimate the global warming significance of methane by 1.6-fold compared to more recent values for the 100-year time frame and by four to fivefold compared to the 10- to 20-year time frames [34, 37].

Climate Impacts of Different Natural Gas Uses

In Howarth et al. [8], we compared the greenhouse gas emissions of shale gas and conventional natural gas to those of coal and oil, all normalized to the same amount of heat production (i.e., g C of carbon dioxide equivalents per MJ of energy released in combustion). We also noted that the specific comparisons will depend on how the fuels are used, due to differences in efficiencies of use, and briefly discussed the production of electricity from coal versus shale gas as an example; electric-generating plants on average use heat energy from burning natural gas more efficiently than they do that from coal, and this is important although not usually dominant in comparing the GHGs of these fuels [8, 18–20]. We presented our main conclusions in the context of the heat production (Fig. 1), though, because evaluating the GHGs of the different fossil fuels for all of their major uses was beyond the scope of our original study, and electricity production is not the major use of natural gas. This larger goal of separately evaluating the GHGs of all the major uses of natural gas has not yet been taken on by other research groups either.

In Figure 5 (left-hand panel), I present an updated comparison of the GHGs of natural gas, diesel oil, and coal based on the best available information at this time (April 2014). Values are expressed as g C of carbon dioxide equivalents per MJ of energy released as in our 2011 paper [8] and Figure 1. The methane emissions in Figure 5 are the mean and range of estimates from the recent review by Brandt and colleagues [29] (see Fig. 2), normalized to carbon dioxide equivalents using the 20-year mean GWP value of 86 from the latest IPCC assessment [34]. As noted above, I believe the 20-year GWP is an appropriate timescale, given the urgent need to control methane emissions globally. Estimates for coal and diesel oil are from our 2011 paper [8], using data for surface-mined coal since that dominates the U.S. market [20]. The direct and indirect emissions of carbon dioxide are combined and are the same values as in Howarth et al. [8] and Figure 1. Direct carbon dioxide emissions follow the High Heating Value convention [2, 8]. Clearly, using the best available data on rates of methane emission [29], natural gas has a very large GHG per unit of heat generated when considered at this 20-year timescale.

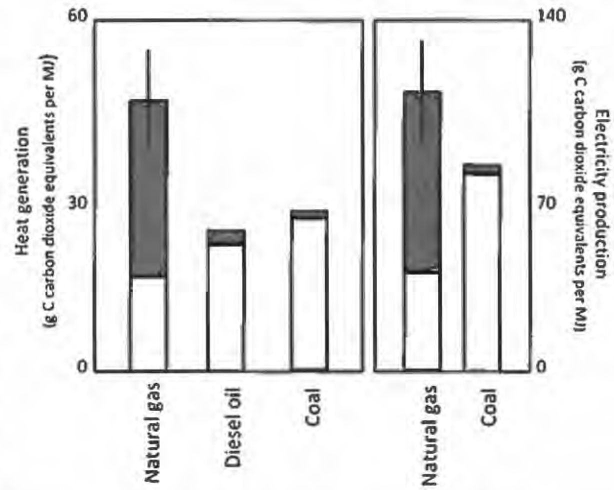

Figure 5. Comparison of the greenhouse gas footprint for using natural gas, diesel oil, and coal for generating primary heat (left) and for using natural gas and coal for generating electricity (right). Direct and indirect carbon dioxide emissions are shown in yellow and are from Howarth et al. [8], while methane emissions shown as g C of carbon dioxide equivalents using the 2013 IPCC 20-year GWP [34] are shown in red. Methane emissions for natural gas are the mean and range for the U.S. national average reported by Brandt and colleagues [29] in their supplemental materials. Methane emissions for diesel oil and for coal are from Howarth et al. [8] For the electricity production, average U.S. efficiencies of 41.8% for gas and 32.8% for coal are assumed [20]. Several studies present data on emissions for electricity production in other units. One can convert from g C of CO_2-equivalents per MJ to g CO_2-equivalents per kWh by multiplying by 13.2. One can convert from g C of CO_2-equivalents per MJ to g C of CO_2-equivalents per kWh by multiplying by 3.6.

Of the studies listed in Tables 1 and 2 published after our 2011 paper [8], most focused just on the comparison of natural gas and coal to generate electricity, although one also considered the use of natural gas as a long-distance transportation fuel [40]. For context, over the period 2008–2013 in the United States, 31% of natural gas has been used to generate electricity and 0.1% as a transportation fuel [50]. None of the studies listed in Tables 1 and 2, other than Howarth et al. [8], considered the use of natural gas for its primary use: as a source of heat. In the United States over the last 6 years, 32% of natural gas has been used for residential and commercial heating and 28% for industrial process energy [50]. The focus on electricity is appropriate if the only question at hand is "how does switching out coal for natural gas in the generation of electricity affect greenhouse gas emissions?" However, policy approaches have pushed other uses of natural gas – without any scientific support – as a way to reduce greenhouse gas emissions, apparently on the mistaken belief that the analysis for electricity generation applied to these other uses. Before exploring some of these other uses of natural gas, I would like to further explore the question of electricity generation.

Many of the papers listed in Tables 1 and 2 concluded that switching from coal to natural gas for generating electricity has a positive influence on greenhouse gas emissions. Note, though, that for almost all of these papers, the conclusion was driven by a focus on only the 100-year timescale [4, 12–14, 16, 17, 29, 39], on a very low assumed level of methane emission [4, 12–14, 17, 39], or both. The differences in efficiency of use in electric power plants, comparing either current average plants or best possible technologies, are relatively small compared to the influence of the GWP on the calculation [8, 18, 20, 40]. Using a 20-year GWP framework and the methane emission estimates from Howarth et al. [8], the GHG from generating electricity with natural gas is larger than that from coal [8, 18–20]. Alvarez and colleagues [40] concluded that for electricity generation, the GHG of using natural gas was less than for coal for all time frames only if the rate of methane leakage was less than 3.2%. Their analysis used the estimates for the radiative forcing of methane from the IPCC 2007 synthesis [36], and if we correct their estimate for the data in the 2013 IPCC assessment [34], this "break-even point" becomes 2.8%. If we further consider the uncertainty in the radiative forcing of methane of 30% or more [34], this "break-even" value becomes a range of 2.4–3.2%.

In Figure 5 (right-hand panel), I compare the GHGs of natural gas and coal when used to generate electricity, again using the High Heating Value convention [2, 8], the latest IPCC value for the 20-year GWP [34] and the range of methane emission estimates reported by Brandt and colleagues [29]. No distinction is made for less downstream emissions for the pipelines that feed electric power plants, as is assumed in several other studies [12–14, 16], simply because no data exist with which to tease apart downstream emissions specific for electric power generation [51]. This analysis uses the average efficiency for electric power plants currently operating in the United States, 41.8% for gas and 32.8% for coal [20]. The emissions per unit of energy produced as electricity are higher than for the heat generation alone, due to these corrections for efficiency. Although the difference in the footprints for using the two fuels is less for the electricity comparison than for the comparison for heat generation, at this 20-year timescale the GHG of natural gas remains greater than that of coal, even at the low-end methane emission estimate. This conclusion still holds when one compares the fuels using the best available technologies (50.2% efficiency for natural gas and 43.3% for coal [20]); the emissions per unit of electricity generated decrease for both by approximately the same amount.

For the dominant use of natural gas – heating for water, domestic and commercial space, and industrial process energy – the analysis we presented in our 2011 paper [8] and shown in Figure 1 remains the only published study before this new analysis shown in Figure 5 (left-hand panel). The updated version shown here compellingly indicates natural gas is not a climate-friendly fuel for these uses. However, the greenhouse gas consequences may in fact be worse than Figure 5 or Howarth et al. [8] indicate, as I discuss next.

A recent study supported by the American Gas Foundation promoted the in-home use of natural gas over electricity for appliances (domestic hot water, cooking) because of a supposed benefit for greenhouse gas emissions [52]. The report argues that an in-home natural gas appliance will have a higher efficiency in using the fuel (up to 92%) compared to the overall efficiency of producing and using electricity ("only about 40%," according to this study). However, they did not include methane emissions in their analysis, nor did they consider the extremely high efficiencies available for some electrical appliances, such as in-home air-sourced heat pumps for domestic hot water. For a given input of electricity, such heat pumps can produce 2.2-times more heat energy, since they are harvesting and concentrating heat from the local environment [53]. In a comparison of using in-home gas-fired water heaters or in-home high-efficiency electric heat pumps, with the electricity for the heat pumps generated by burning coal, the heat pumps had a lower GHG than did in-home use of gas if the emission rate for methane was greater than 0.7% for a 20-year GWP or 1.3% for a 100-year GWP [51]. Using the mean methane emission estimate from Howarth et al. [8] for conventional natural gas (Fig. 2) and a 20-year GWP, the in-home natural gas heater had a GHG that was twice as large as that of the heat pump [51]. Of course, an in-home heat pump powered by electricity from renewable sources such as wind and solar would have a far smaller GHG yet [54].

What about other uses of natural gas? The "Natural Gas Act," a bill introduced in the United States Congress in 2011 with bipartisan support and the backing of President Obama, would have provided tax subsidies to encourage the replacement of diesel fuel by natural gas for long-distance trucks and buses; the bill did not pass, in part because conservatives opposed it as "market distorting" [55, 56]. In Quebec, industry has claimed that this replacement of diesel by shale gas would reduce greenhouse gas emissions by up to 30% [57]. However, in contrast to a possible advantage in replacing coal with natural gas for electricity generation (if methane emissions can be kept low enough), using natural gas to replace diesel fuel as a long-distance transportation fuel would greatly increase greenhouse emissions [29, 40]. In part, this is because the energy of natural gas is used with less efficiency than diesel in truck engines. Furthermore, although methane emissions from transportation systems have not been well measured, one could imagine significant emissions during refueling operations for buses and trucks, as well as from venting of on-vehicle natural gas tanks to keep gas pressures significantly safe during warm weather. Despite the findings of Alvarez and colleagues published in 2012 [40], the EPA continues to indicate that switching buses from diesel fuel to natural gas reduces greenhouse gas emissions [58].

Concluding Thoughts

By 1950, which is about the time I was born, human activity had contributed enough greenhouse gases to the atmosphere to cause a radiative forcing – the driving factor behind global warming – of 0.57 watts m^{-2} compared to before the industrial revolution [34]. Thirty years later, in 1980 when I taught my first course on the biosphere and global change, this human influence had doubled the anthropogenic radiative forcing, to 1.25 watts m^{-2} [34]. And another 30 years later, the continued release of greenhouse gases by humans has again doubled the forcing, now at 2.29 watts m^{-2} or fourfold greater than just 60 years ago [34]. The temperature of the Earth continues to rise in response at an alarming rate, and the climate scientists tell us we may reach dangerous tipping points in the climate system within just a few decades [34, 41, 42]. Is it too late to begin a serious reduction in greenhouse gas emissions? I sincerely hope not, although surely society has been very slow to respond to this risk. The use of fossil fuels is the major cause of greenhouse gas emissions, and any genuine effort to reduce emissions must begin with fossil fuels.

Is natural gas a bridge fuel? At best, using natural gas rather than coal to generate electricity might result in a very modest reduction in total greenhouse gas emissions, if those emissions can be kept below a range of 2.4–3.2% (based on [40], adjusted for the latest information on radiative forcing of methane [34]). That is a big "if," and one that will require unprecedented investment in natural gas infrastructure and regulatory oversight. For any other foreseeable use of natural gas (heating, transportation), the GHG is larger than if society chooses other fossil fuels, even with the most stringent possible control on methane emissions, if we view the consequences through the decadal GWP frame. Given the sensitivity of the global climate system to methane [41, 42], why take any risk with continuing to use natural gas at all? The current role of methane in global warming is large, contributing 1.0 watts m^{-2} out of the net total 2.29 watts m^{-2} of radiative forcing [34].

Am I recommending that we continue to use coal and oil, rather than replace these with natural gas? Not at all. Society needs to wean itself from the addiction to fossil fuels as quickly as possible. But to replace some fossil fuels (coal, oil) with another (natural gas) will not suffice as an approach to take on global warming. Rather, we should embrace the technologies of the 21st Century, and convert our energy systems to ones that rely on wind, solar, and water power [59, 60, 61]. In Jacobson et al. [54], we lay out a plan for doing this for the entire state of New York, making the state largely free of fossil fuels by 2030 and completely free by 2050. The plan relies only on technologies that are commercially available at present, and includes modern technologies such as high-efficiency heat pumps for domestic water and space heating. We estimated the cost of the plan over the time frame of implementation as less than the present cost to the residents of New York from death and disease from fossil fuel caused air pollution [54]. Only through such technological conversions can society truly address global change. Natural gas is a bridge to nowhere.

Acknowledgments

Funding was provided by Cornell University, the Park Foundation, and the Wallace Global Fund. I thank Bongghi Hong, Roxanne Marino, Tony Ingraffea, George Woodwell, and two reviewers who have asked to remain anonymous for their valuable comments on earlier drafts of the manuscript.

Conflict of Interest

None declared.

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EMP Update
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December 4, 2015

Re: Comments of the American Wind Energy Association in Response to the Draft New Jersey 2011 Energy Master Plan Update

Submitted via email to EMPupdate@bpu.state.nj.us

On November 20, 2015, the New Jersey Board of Public Utilities (BPU) announced the availability for public comment of the Draft New Jersey 2011 Energy Master Plan Update (Master Plan Update). The American Wind Energy Association (AWEA) appreciates the opportunity to provide the following comments on the Master Plan Update and looks forward to working with the BPU to advance the wind energy development goals identified in the 2011 Energy Master Plan and subsequent revisions.

AWEA is the national trade association representing a broad range of entities with a common interest in encouraging the deployment and expansion of wind energy resources in the United States. AWEA members include wind turbine manufacturers, component suppliers, project developers, project owners and operators, financiers, researchers, renewable energy supporters, utilities, marketers, customers and their advocates.

In the Master Plan Update, the Energy Master Plan Committee has identified several key goals including "driving down the cost of energy for all customers" while "maintaining support for the renewable energy portfolio standard" and "promoting a diverse portfolio of new, clean in-state generation". Wind energy, both land-based and offshore, stands ready to support these goals.

Recently, the U.S. Department of Energy (DOE) released data showing the cost of wind energy has fallen by nearly two-thirds over the last six years. Recent data from financial services company Lazard compares levelized ("unsubsidized") costs of energy from various sources and demonstrates that, even at recent low natural gas prices, the range of costs for wind is even lower.[i] Long term contracts for wind power are now at historic lows, saving consumers money. Wind power is now the most cost-effective form of electricity generation for limiting carbon emissions and wind provides a valuable hedge against fossil fuel price volatility, which protects consumers.

Wind energy technology has recently developed to allow productive deployment in areas that previously were not considered viable, providing New Jersey greater flexibility in evaluating in-state wind energy opportunities. Although the wind energy resource in New Jersey is limited relative to many neighboring states, taller towers, longer blades and improvements to turbine drivetrain technology may provide opportunities for projects in the Garden State. A recent update of the DOE "Wind Vision" scenario projects that New Jersey's land-based wind resources could produce enough wind energy by 2030 to power the equivalent of 972,000 average American homes and, according to an analysis prepared by the DOE's National Renewable Energy Laboratory, if fully developed, the Wind Energy Area recently leased off shore New Jersey could support about 3,400 megawatts of commercial wind generation, which is enough electricity to power about 1.2 million homes. New Jersey also benefits from proximity to several major wind producing states and is therefore well positioned to reduce electricity costs and advance Energy Master Plan goals by considering long term contracting opportunities for wind energy, especially within the PJM region.

Offshore wind continues to represent a major opportunity for New Jersey to advance the Energy Master Plan goals as evidenced by the Energy Master Plan's continuing policy recommendation to "support offshore wind". Governor Christie was widely praised for signing the Offshore Wind Economic Development Act (OWEDA) into law in 2010, noting at that time that "Developing New Jersey's renewable energy resources and industry is critical to our state's manufacturing and technology future". However, since that time, the BPU has not adopted regulations pursuant to that law, frustrating offshore wind development efforts.

Developing offshore wind is important for New Jersey because it can bring private-sector jobs and investment to the state. There are currently over 58,000 jobs in the global offshore wind industry, with growth expected up to 191,000 in 2020. Annual investment in offshore wind is projected to average over $20 billion per year for the next ten years, with significant investment on the U.S. East Coast. Capturing even a portion of this industry would be a boon to New Jersey's economy.

But it's not just about jobs. Offshore wind can be a cost-effective source of energy for New Jersey. OWEDA requires that offshore wind farms demonstrate net economic benefits for the state and we are confident that, when all the benefits are properly counted, New Jersey offshore wind will pay for itself. Offshore wind will help to stabilize energy prices, enhance energy security, diversify the state's energy sources, and make a significant contribution to reducing the state's greenhouse gas emissions. And, as a local source of energy, offshore wind will keep more of the state's energy expenditures in New Jersey, multiplying its economic benefits.

Given these many benefits, offshore wind is very popular in New Jersey. A recent poll by Monmouth University found that 75% of New Jersey voters favor offshore wind and that 63% thought it should be a priority of the Christie Administration. Therefore, we urge the BPU to expeditiously adopt regulations, pursuant to OWEDA, to implement an offshore wind renewable energy certificate program. Finalization of a regulatory structure for offshore wind energy in New Jersey is critical to meeting the goals enumerated in the Energy Master Plan and articulated by Governor Christie.

AWEA and its members appreciate the opportunity to comment in response to the Draft New Jersey 2011 Energy Master Plan Update. We look forward to working with the BPU and other stakeholders to support the goals of the Energy Master Plan and communicate the benefits of wind energy in advancing those goals.

Sincerely,

Andrew Gohn
Eastern Region Director, State Policy
American Wind Energy Association

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[i] Lazard's Levelized Cost of Energy Analysis - Version 9.0, 2015 https://www.lazard.com/media/2390/lazards-levelized-cost-of-energy-analysis-90.pdf