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Monetizing Health Benefits of Offshore Wind Expansion and Demand Reduction Strategies in New Jersey

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Executive Summary

New Jersey's Energy Master Plan (EMP) and Executive Orders 307 and 315 establish a framework for comprehensive clean energy strategies that can have a measurable impact on public health. Central to the EMP is the goal of reducing electricity demand by 20% by 2035, fostering investments in energy efficiency, electric vehicle promotion, and building electrification. Additionally, Executive Order (EO) 92 issued in 2019 set a target for New Jersey to generate 7,500 megawatts of offshore wind power by 2035, and in 2022, EO 307 increased that target for New Jersey to generate 11,000 megawatts of offshore wind power by 2040. These initiatives align with EO 315, signed by Governor Murphy in 2023, mandating a 100% clean energy target by 2035.

The analysis presented in this report investigates the potential health effects of strategies outlined in the EMP and EO 92 focusing on offshore wind and demand reduction. To accomplish this, advanced operations research models are employed to determine optimal electricity dispatch decisions that align with the 2035 targets set by these policies. By limiting our scope to the 2035 milestones outlined by the EMP and EO 92, we ensure a consistent framework for assessment and decision-making while ensuring that decision variables in our optimization model operate on the same time scale. Additionally, we estimate NO_X, SO_2, CO_2 and CH_4 emissions projections associated with these strategies and evaluate the resulting statewide health benefits of NO_X and SO_2 emissions reductions using an EPA-developed air quality screening tool called the Co-Benefits Risk Assessment (or COBRA).

The COBRA model estimates the health and economic impacts of air pollution changes. This tool quantifies these effects in terms of both the reduction in health effects and their corresponding economic values. The model specifically provides estimates for a range of health outcomes, including both adult and infant mortality, non-fatal heart attacks, hospital admissions related to respiratory and cardiovascular conditions, cases of acute bronchitis, symptoms affecting the upper and lower respiratory tract, exacerbations and emergency room visits due to asthma, days with minor restricted activities, and lost workdays [8]. This comprehensive approach allows COBRA to monetize the health benefits of reducing air pollution, thus enabling policymakers to understand the economic implications of environmental health interventions.

Using our operations research dispatch models in tandem with the COBRA screening model, we investigate the following scenarios in this study:

1. *Electricity Demand Reduction:* In this scenario, using our dispatch model, we have identified the optimal plan for electricity dispatch to meet demand, aligning with the demand reduction targets set forth in the EMP.
2. *Wind Energy Expansion:* Utilizing our dispatch model, in this scenario, we have delineated the optimal strategy for electricity dispatch, while incorporating the additional offshore wind capacity as stipulated in EO 92.
3. *Synergistic Energy Integration:* In this scenario, we determine the optimal electricity dispatch strategy that meets demand reduction targets per the EMP and integrates the increased offshore wind capacity required by EO 92 in a single approach..

In our analysis using the COBRA model to assess the statewide health benefits stemming from NO_X and SO_2 emissions reductions, the *Synergistic Energy Integration* scenario yields the largest benefit with an economic value ranging from \$13.3 billion to \$30 billion over the modeled time period of 2021 to 2035. Furthermore, this strategy significantly reduces CO_2 and CH_4 emissions in addition to the reductions in NO_X and SO_2 emissions. Following closely, the *Wind Energy Expansion* scenario offers statewide health benefits estimated between \$9.2 billion and \$20.9 billion from 2021 to 2035. This scenario benefits from an optimal dispatch plan that increases generation from expanded offshore wind capacity, effectively displacing energy production from fossil fuel sources and thus reducing CO_2 and CH_4 emissions in addition to NO_X, and SO_2 emissions. Lastly, the *Electricity Demand Reduction* scenario, covering analyses from 2021 to 2035, is projected to achieve statewide health benefits ranging from approximately \$4 billion to \$9 billion. Although this scenario also reduces NO_X, SO_2, CO_2, and CH_4 emissions, the reductions—and consequently the health benefits from NO_X and SO_2 emissions reductions—are less substantial than those achieved through the other two scenarios.

This analysis provides initial insights into potential statewide health benefits from adoption of clean energy pathways in New Jersey. Additionally, it points to areas for future research, such as extending the time horizon to include the additional 2040 offshore wind targets, the impact of the Solar Act of 2021, and other potential pathways, the impact on consumer prices, determining optimal investment strategies, and incorporating power purchase agreements into the analysis framework.

Background Information and Motivation

The Energy Master Plan (EMP) of New Jersey, in conjunction with Executive Orders (EOs) 92, 307, and 315, lays out a comprehensive and strategic framework specifically designed to achieve significant and measurable improvements in public health outcomes. One of the primary objectives of the EMP is to cut electricity consumption across the state by 20% by 2035 [1]. This goal is underpinned by a multi-faceted strategy that includes promoting substantial investments in energy efficiency initiatives, accelerating the adoption of electric vehicles, and encouraging the transition to electrification in building infrastructures. Such measures are critical for addressing and mitigating the adverse health effects of air pollution, notably respiratory ailments like asthma and, chronic obstructive pulmonary disease (COPD) and cardiovascular diseases, which have been linked to pollutants emitted by traditional energy sources [2].

EO 92, issued in 2019, set a target of 7,500 megawatts of new offshore wind capacity by 2035 to meet clean energy goals, strengthen the state's economy, and position New Jersey as a leader in renewable energy production [3]. Subsequently, EO 307, issued in 2022, expands upon EO 92 to establish a new target of 11,000 megawatts of offshore wind power generation by 2040 [4]. This initiative underscores New Jersey's commitment to expanding renewable energy sources and positions the state as a leader in the transition towards more sustainable and environmentally friendly power generation methods.

Building upon this foundation, EO 315, signed in 2023, further amplifies New Jersey's environmental and health ambitions by mandating a transition to 100% clean energy by 2035 [5]. This directive aligns with the broader goals of the EMP, reinforcing the state's dedication to combating climate change, reducing reliance on fossil fuels, and ensuring a healthier environment for its residents. These policies and targets collectively form a blueprint for New Jersey's energy future through innovative and sustainable energy solutions.

Our analysis centers on investigating the following scenarios outlined in the EMP to facilitate clean energy goals:

- *Scenario #1: Electricity Demand Reduction:* In this scenario, we examine the impact of the electricity demand reduction goal of 20% by 2035, as proposed in the EMP, on the energy mix and health benefits. Specifically, we use deterministic operations research models to examine the optimal sequencing of electricity dispatch decisions at least cost and quantify the resulting health benefits of the projected dispatching decisions post-optimally.

- *Scenario #2: The Wind Energy Expansion:* This scenario guides us through the state's expansion of wind energy capacity, guided by EO 92. Specifically, to align with the timeline in Scenario #1, we consider the short-term target of 7,500 megawatts of offshore wind expansion by 2035. We leverage deterministic operations research models for electricity dispatch decisions and conduct comprehensive post-optimally health benefit assessments to accomplish this.
- *Scenario #3: Synergistic Energy Integration:* This scenario, representing an integration of strategies from Scenario #1 and Scenario #2, provides insights into the interplay between demand reduction strategies and offshore wind expansion.

A fundamental dimension of our analysis revolves around exploring and quantifying statewide health benefits associated with NO_X and SO_2 emissions reductions. While these benefits are acknowledged at a high level in the EMP, the analysis presented in this report presents a more detailed assessment of these benefits on a county-level and as a function of key health effects. This analysis also complements the New Jersey Global Warming Response Act 80x50 Report, which proposes environmental strategies to reduce short-lived climate pollutants and greenhouse gases such as CH_4, halogenated gases, and black carbon rather than directly addressing health-related consequences [6].

Methods and Findings

This report is aligned with New Jersey's commitment to advancing toward a clean energy future and aims to evaluate three distinct energy generation scenarios that are aligned with the pathways outlined in the Energy Master Plan (EMP) and EO 92. To assess the optimal dispatch plan under each scenario, we employ the Generation Expansion Planning (GEP) model, developed by Rodgers et al. [7], spanning the planning horizon from 2021 to 2035, in alignment with New Jersey's strategies and incorporating planned wind investments. Next, to evaluate the resulting statewide health effects of the scenarios under consideration, the resulting NO_X and SO_2 emissions from the corresponding dispatch plans are then evaluated using a U.S. Environmental Protection Agency (EPA) screening tool called Co-Benefits Risk Assessment (COBRA).

The COBRA model assesses the health and economic impacts of air pollution changes, leveraging the Source-Receptor (S-R) Matrix, a simplified air quality model, to geospatially evaluate how emissions affect ambient particulate matter (PM) [8]. It quantifies these effects in terms of both the reduction in health effects and their corresponding economic values. The model specifically provides estimates for a range of health outcomes, including both adult and infant mortality, non-fatal heart attacks, hospital admissions related to respiratory and cardiovascular conditions, cases of acute bronchitis, symptoms affecting the upper and lower respiratory tract, exacerbations and emergency room visits due to asthma, days with minor restricted activities, and lost workdays [8]. This comprehensive approach allows COBRA to monetize the health benefits of reducing air pollution, thus enabling policymakers to understand the economic implications of environmental health interventions.

Moreover, to ensure a seamless alignment with the objectives of the Energy Master Plan (EMP) and EO 92, our analysis deliberately refrains from considering any investment decisions outside the ambit of the strategies currently under examination. This approach guarantees that our evaluation remains focused and relevant to the overarching goals. Additionally, in recognition of the critical milestones established by the EMP and EO 92 for 2035, our analysis is intentionally scoped not to exceed this temporal boundary, thereby maintaining a coherent and consistent framework for assessment and decision-making. This strategic limitation reinforces the pertinence and applicability of our findings within the specified policy and strategic context, making a compelling case for their adoption and implementation.

The first scenario, *Electricity Demand Reduction*, focuses on reducing electricity needs in line with the EMP's proposed strategies. This analysis utilizes a least-cost generation expansion planning model to determine the optimal sequence of electricity dispatch decisions, aligning demand projections with the EMP's proposed strategies. We also evaluate health co-benefits using the EPA's COBRA tool [8]. The EMP includes initiatives such as energy efficiency programs, clean energy deployment, and grid modernization to reduce electricity demand, projecting a 20% reduction by 2035. This reduction is pivotal in achieving New Jersey's 100% clean energy goal by 2035, facilitating the integration of renewable energy and improving public health through reduced air pollution.

The second scenario, the *Wind Energy Expansion*, employs the least-cost generation expansion planning model and evaluates health co-benefits. This scenario aligns with the EMP's initiatives and EO 92, particularly the accelerated deployment of 7,500 megawatts of offshore wind to reduce fossil fuel reliance and enhance clean energy utilization. New Jersey's target of 100% clean energy by 2035 necessitates a substantial increase in wind capacity, and this analysis aids in identifying optimal investment strategies while considering health co-benefits from reduced air pollution.

The third scenario, *Synergistic Energy Integration*, represents a combination of elements from the first and second scenarios, offering a comprehensive approach to realizing New Jersey's clean energy goals outlined in the EMP.

Drawing on the outcomes of the optimization model, the report presents Table 1, offering a summary of the projected emissions associated with the three strategies above. In the context of New Jersey's clean energy objectives, the *Baseline* scenario represents the current status quo of emissions with no new interventions. The *Electricity Demand Reduction* scenario suggests a modest decrease in pollutants, showcasing the benefits of reducing consumption alone. However, The *Wind Energy Expansion* scenario reflects a more aggressive approach to incorporating wind energy, yielding even lower emissions. The most transformative approach, the *Synergistic Energy*

Integration scenario, results in the most substantial reductions in all categories, indicating that a multi-faceted approach to energy policy can lead to a cleaner environment and help New Jersey progress towards its clean energy targets more effectively than maintaining current practices. These results underscore the significance of integrating multiple strategies to optimize emissions reduction and promote sustainable energy practices in New Jersey.

Table 1: Statewide emissions comparison by scenario

Scenario	NO_x **(tons)**	SO_2 **(tons)**	CO_2 **(tons)**	CH_4 **(lbs)**
Baseline	210,637	6,676	1,230,739,057	47,639,192
Electricity Demand Reduction	181,259	5,745	1,059,082,283	40,994,737
The Wind Energy Expansion	143,830	4,558	840,385,775	32,529,478
Synergistic Energy Integration	114,451	3,627	668,729,002	25,885,023

Next, we present an in-depth analysis of the aggregate electricity dispatch schedule on an annual basis, exploring the outcomes of the scenarios mentioned above in the context of New Jersey's energy generation[1]. First, however, we share the baseline generation projection, which is a reference for current state practices without additional measures applied in the alternative scenarios. As depicted in Figure 1, gas currently constitutes the predominant source of electricity generation, and under this reference scenario, it contributes 55% of the total generation over the planning period. Concurrently, nuclear power occupies a share of 42%, with solar energy representing 2% of the overall generation.

Moving on to the *Wind Energy Expansion* scenario, as summarized in Figure 2, notable transformations in the energy mix are evident. Here, the gas source's share diminishes to 38%, while nuclear power retains its significant 42% share. Solar energy exhibits a consistent contribution at 2%, and the incorporation of wind power becomes discernible, accounting for an 18% share of the total generation.

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[1] The additional 3750 MW solar capacity mandated by the Solar Act of 2021 is not included in the scope of this analysis due to potential uncertainties in existing model parameters that may impact optimization outcomes if included prematurely. This decision ensures the robustness and reliability of our optimization results in the short term, but will be the subject of future investigation in the long term.

Transitioning to the *Electricity Demand Reduction* scenario, outlined in Figure 3, gas plays a significant role, constituting 52% of the total generation throughout the planning horizon. Notably, nuclear power demonstrates an increased share of 46%, while solar energy maintains its 2% contribution. Lastly, Figure 4 elucidates the generation outcomes for the *Synergistic Energy Integration* scenario. In this scenario, the share of gas declines further to 33%, while nuclear power retains its prominent 46% share. Solar energy sustains a consistent 2% contribution, while wind power assumes a noteworthy role, representing 19% of the total generation.

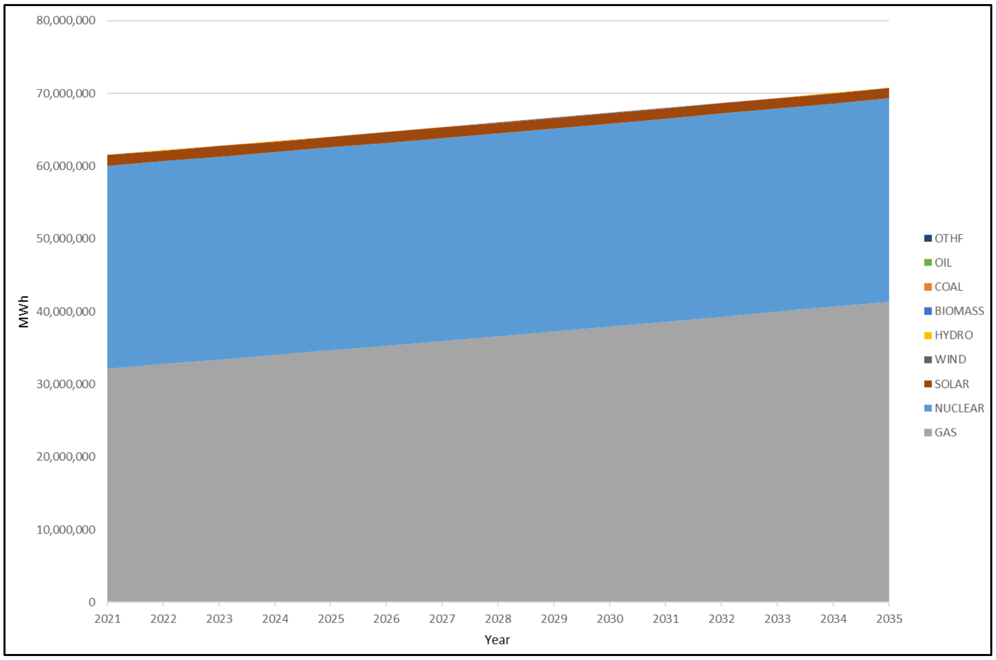

Figure 1: Baseline Dispatch Plan

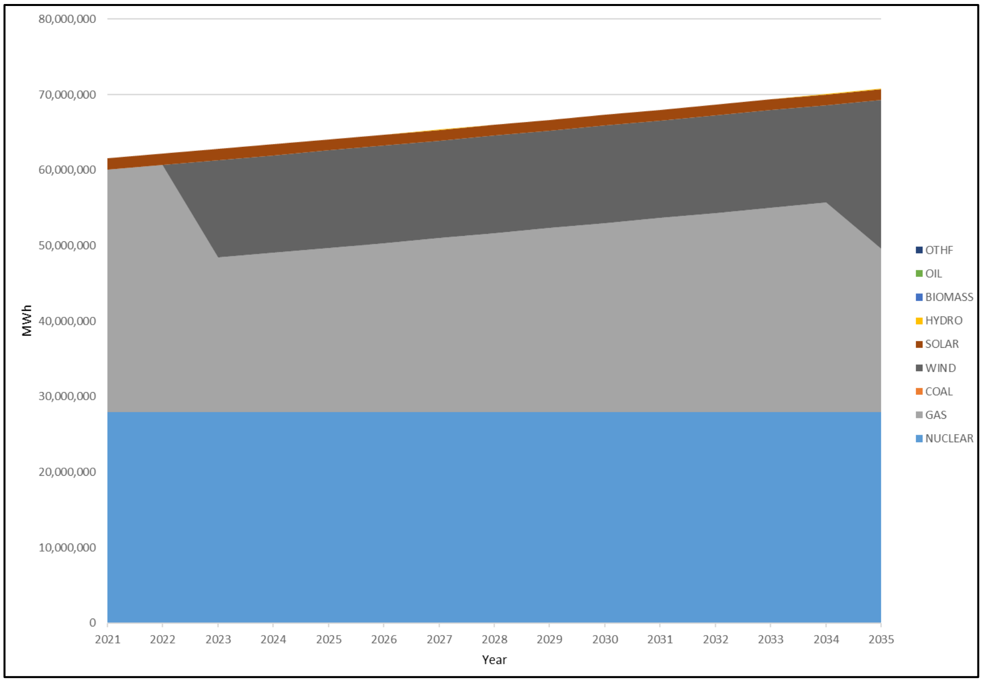

Figure 2: Wind Energy Expansion Dispatch Plan

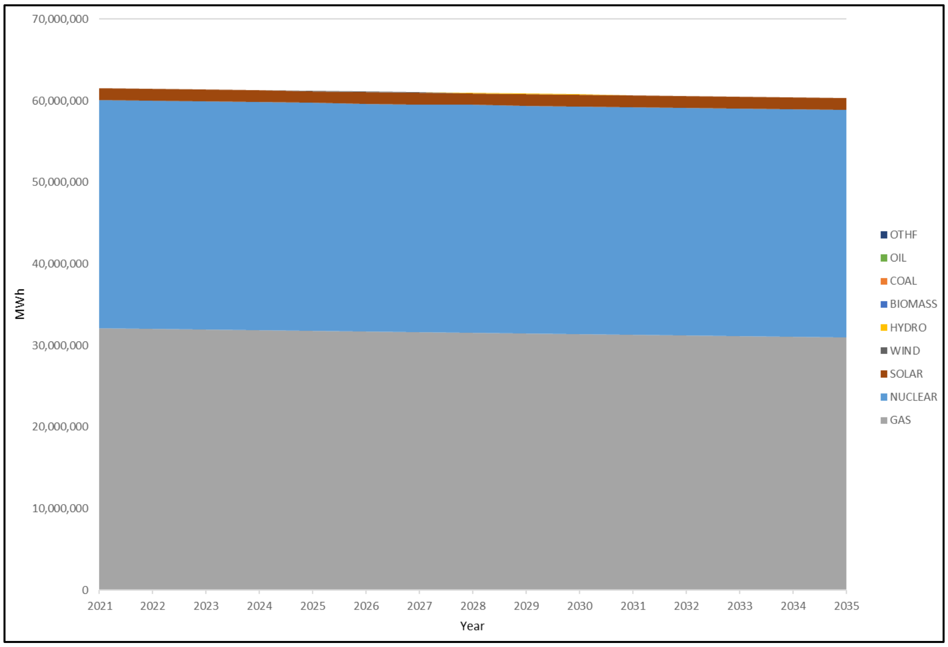

Figure 3: Electricity Demand Reduction Dispatch Plan

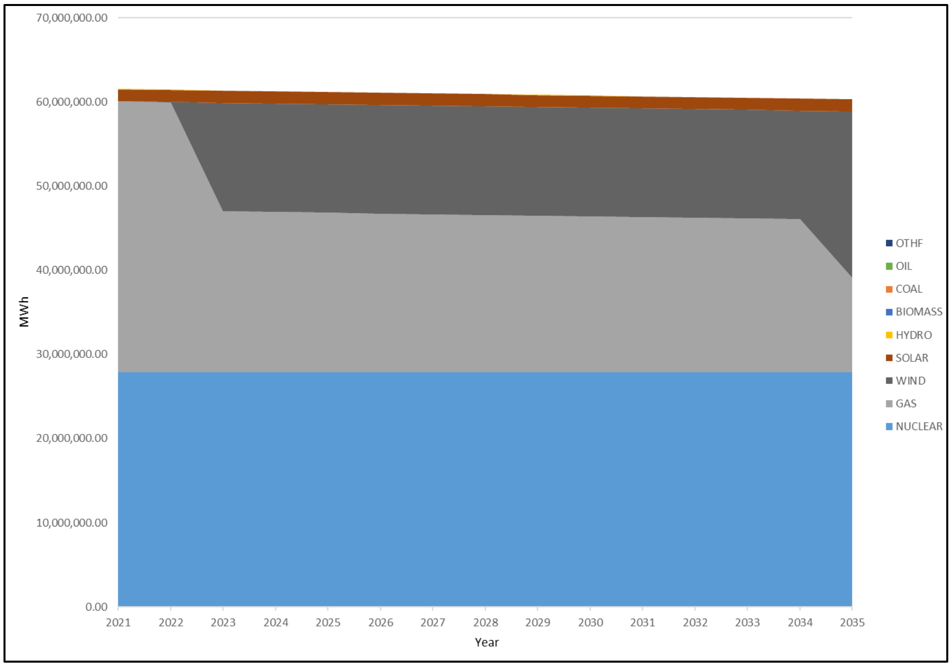

Figure 4: Synergistic Energy Integration Dispatch Plan

Subsequently, this study comprehensively compares the various strategies based on their NOx, SO_2, CO_2, and CH_4 emissions, as visually presented in Figures 5 through 8, respectively. As expected, the baseline strategy exhibits the highest emissions across all pollutant categories. In contrast, the *Electricity Demand Reduction* strategy demonstrates an improvement relative to the baseline, attributed primarily to the reduction in the gas share from 55% to 52%, coupled with an increase in nuclear power's contribution from 42% to 46%. Notably, the *Wind Energy Expansion* scenario yields further emissions reduction, attributable to the incorporation of wind power comprising 18% of the dispatch plan, contributing significantly to curbing emissions. Moreover, compared to the baseline, the Wind Expansion scenario exhibits a notable decrease in the gas share, declining from 55% to 38%. Of particular significance, *Synergistic Energy Integration* presents the most substantial emission reduction advantages. This effect is chiefly due to a further decrease in the gas share to 33%, a higher share of nuclear power at 46%, and a noteworthy contribution from wind power, representing 19% of the dispatch plan. These findings underscore the progressive improvements that can be strategically implemented to address emissions reduction goals effectively. Ultimately, the *Synergistic Energy Integration* emerges as the most promising scenario, embracing a prudent reduction in gas utilization, a strengthened reliance on nuclear power, and the strategic integration of wind power, exhibiting superior potential for achieving significant emission reductions across all assessed pollutant types.

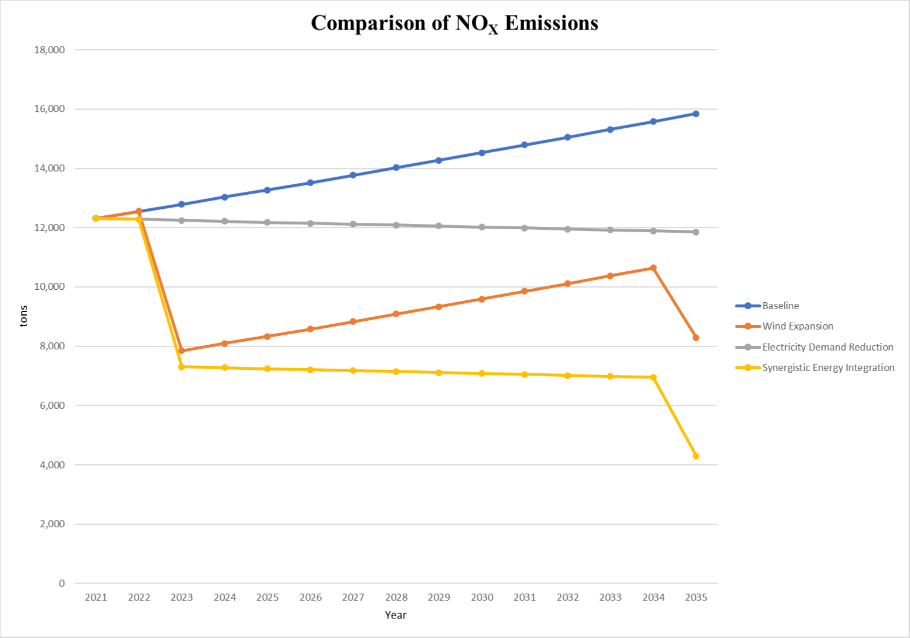

Figure 5: Comparison of strategies for NO_X emissions

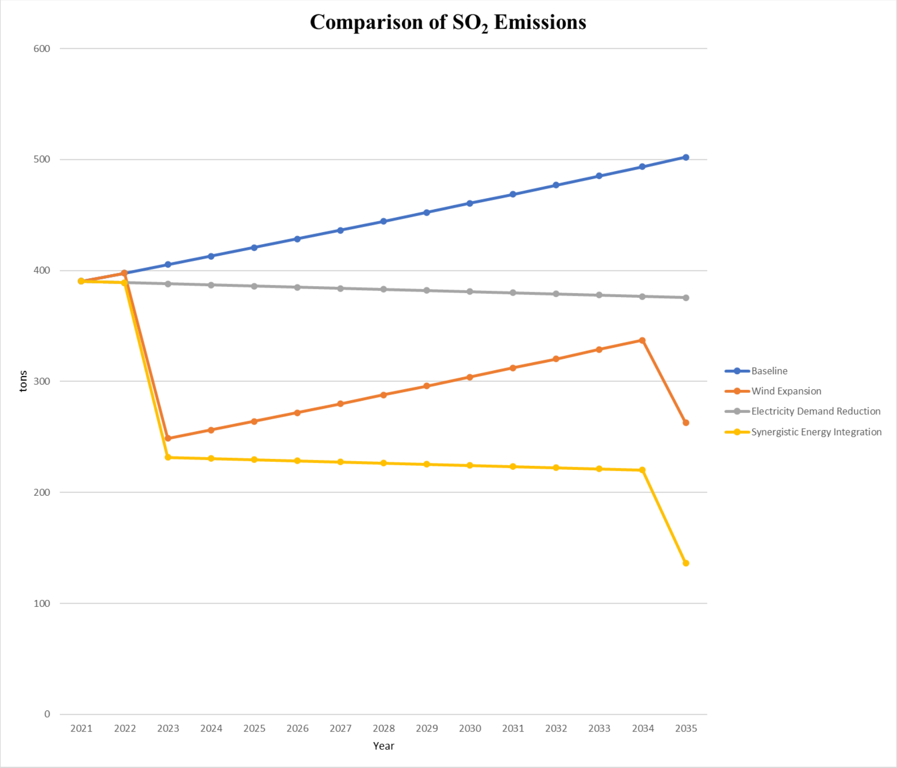

Figure 6: Comparison of strategies for SO_2 emissions

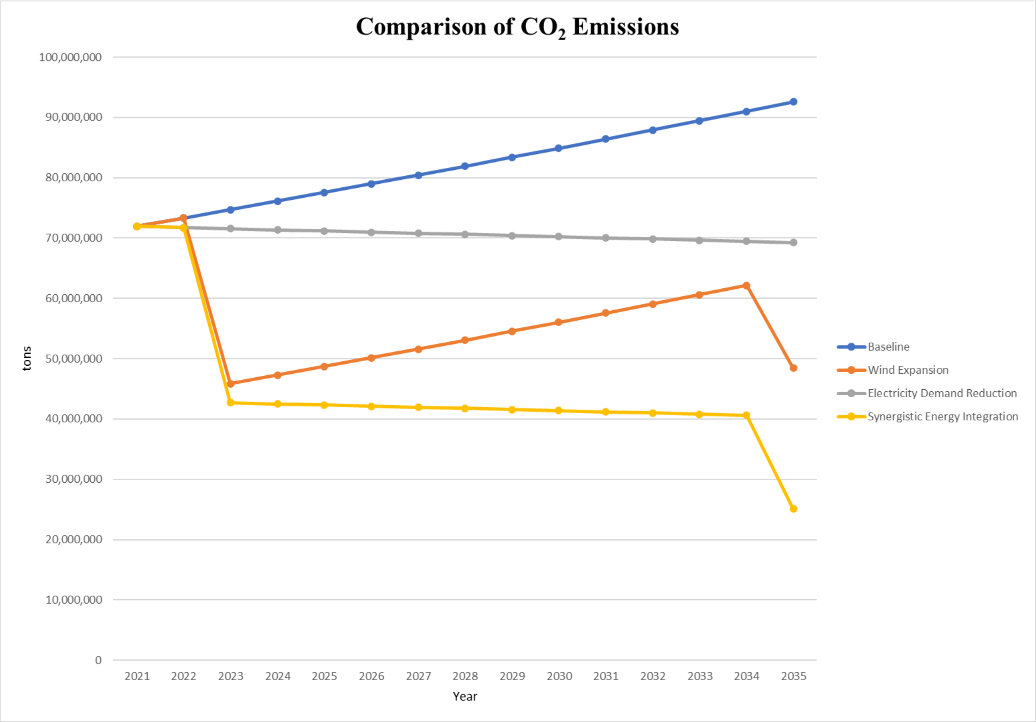

Figure 7: Comparison of strategies for CO_2 emissions

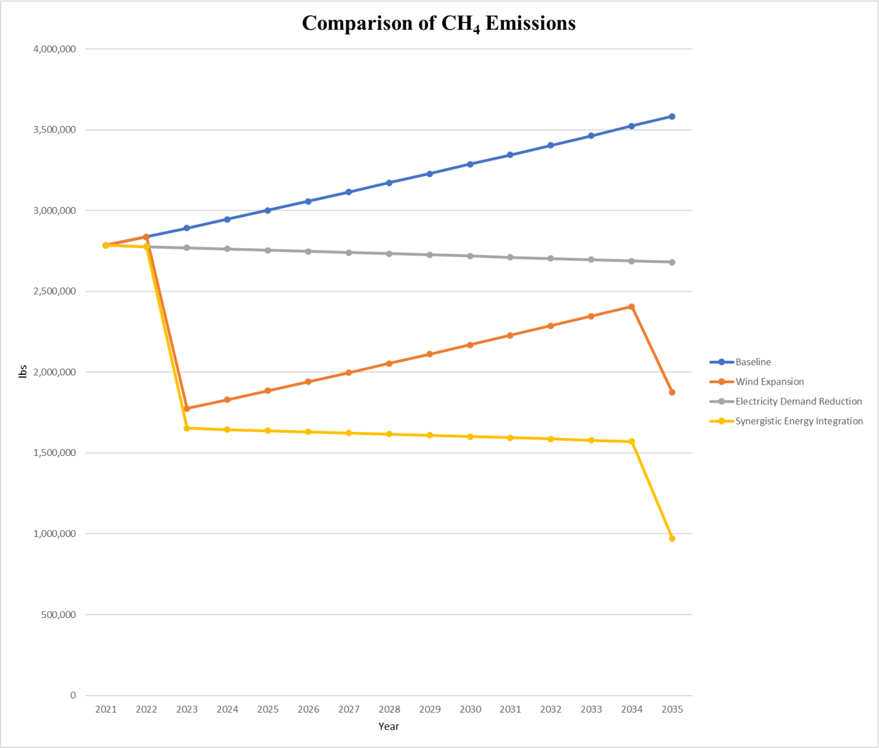

Figure 8: Comparison of strategies for CH_4 emissions

Next, a comprehensive investigation into the statewide health effects associated with each energy generation scenario is presented, employing the EPA's CO-Benefits Risk Assessment (COBRA) screening model at the county-level resolution [8]. This study examines key health effects associated with NO_X and SO_2 emissions, encompassing avoided mortality, avoided infant mortality, avoided hospital admissions, avoided work loss days, and statewide health benefits, as informed by the COBRA tool [8]. Notably, the *Synergistic Energy Integration* emerges as the leading performer in terms of statewide health benefits, followed by the *Wind Energy Expansion* and *Electricity Demand Reduction* strategies, in that order, thereby showcasing the most favorable health metrics. This outcome aligns cohesively with the earlier findings, as the *Synergistic Energy Integration* also demonstrates the most considerable emissions reduction in NO_x, SO_2, CO_2, and CH_4.

Table 2: Total Estimated Statewide Health Co-Benefits from COBRA (2021 through 2035)

Scenario	Economic Benefits ($)		Frequency of Health Effects (Top 80% of Occurrences)						
	$ Total Health Benefits (low estimate)	$ Total Health Benefits(high estimate)	Avoided mortality (low estimate)	Avoided mortality (high estimate)	Avoided Infant Mortality	Avoided Total Hospital Admits	Avoided Hospital Admits, All Respiratory	Avoided Hospital Admits, Cardiovascular (except heart attacks)	Avoided Work Loss Days
Electricity Demand Reduction	4,060,606.08	9,163,147.69	0.36	0.83	0.00	0.18	0.09	0.09	46.22
The Wind Energy Expansion	9,281,351.27	20,944,163.95	0.83	1.89	0.00	0.20	0.20	0.22	105.64
Synergistic Energy Integration	13,341,904.36	30,107,041.54	1.20	2.71	0.00	0.60	0.29	0.31	151.86

Furthermore, Table 2 provides the COBRA output, illustrating the statewide economic value of avoided health effects, including mortality, work loss days, and hospital admissions for all strategies across all counties. Tables 3, 4, and 5 offer a comprehensive breakdown across the 3 scenarios within the scope of this analysis, implemented within New Jersey's 21 counties. These tables offer a detailed analysis of the health effects presented in Table 2, providing specific outcomes for each county. Middlesex, Bergen, and Ocean counties exhibit the most pronounced benefits from these strategies, demonstrating the most significant positive impacts on the outlined health effects. However, it is important to note that these results have not been normalized to account for population differences. Furthermore, the health effects presented in these tables represent the top 80% of all indices that contribute to the total statewide health benefits.

Table 3: The Wind Energy Expansion – Total Estimated Statewide Health Co-Benefits from COBRA by County (2021 through 2035)

County	Economic Benefits ($)		Frequency of Health Effects (Top 80% of Occurrences)						
	$ Total Health Benefits(low estimate)	$ Total Health Benefits(high estimate)	Avoided Mortality (low estimate)	Avoided Mortality(high estimate)	Avoided Infant Mortality	Avoided Total Hospital Admits	Avoided Hospital Admits, All Respiratory	Avoided Hospital Admits, Cardiovascular (except heart attacks)	Avoided Work Loss Days
Atlantic	271,656.84	613,100.63	0.02	0.06	0.00	0.01	0.01	0.01	2.64
Bergen	1,097,094.77	2,472,352.61	0.10	0.22	0.00	0.03	0.03	0.03	13.32
Burlington	494,443.52	1,114,868.66	0.04	0.10	0.00	0.01	0.01	0.01	4.77
Camden	404,597.76	912,253.24	0.04	0.08	0.00	0.01	0.01	0.01	4.06
Cape May	75,356.70	170,202.17	0.01	0.02	0.00	0.00	0.00	0.00	0.43
Cumberland	82,708.33	186,552.46	0.01	0.02	0.00	0.00	0.00	0.00	0.86
Essex	711,858.99	1,607,344.32	0.06	0.14	0.00	0.01	0.01	0.02	9.85
Gloucester	620,653.93	1,407,975.52	0.06	0.13	0.00	0.02	0.02	0.02	5.89
Hudson	300,825.09	675,336.23	0.03	0.06	0.00	0.01	0.01	0.01	5.80
Hunterdon	78,711.25	178,174.21	0.01	0.02	0.00	0.00	0.00	0.00	0.81
Mercer	274,418.30	619,067.55	0.02	0.06	0.00	0.01	0.01	0.01	3.38
Middlesex	1,391,927.38	3,141,623.86	0.13	0.28	0.00	0.02	0.02	0.02	18.67
Monmouth	744,600.64	1,682,114.84	0.07	0.15	0.00	0.02	0.02	0.02	7.20
Morris	305,681.60	689,871.61	0.03	0.06	0.00	0.01	0.01	0.01	3.40
Ocean	1,013,881.91	2,289,121.15	0.09	0.21	0.00	0.02	0.02	0.02	6.64
Passaic	180,529.37	406,974.92	0.02	0.04	0.00	0.00	0.00	0.00	2.40
Salem	47,634.74	107,690.25	0.00	0.01	0.00	0.00	0.00	0.00	0.37
Somerset	222,095.76	500,506.36	0.02	0.05	0.00	0.01	0.01	0.01	2.79
Sussex	84,942.14	191,810.79	0.01	0.02	0.00	0.00	0.00	0.00	0.80
Union	826,564.55	1,861,793.37	0.07	0.17	0.00	0.01	0.01	0.02	11.10
Warren	51,167.70	115,429.19	0.00	0.01	0.00	0.00	0.00	0.00	0.47

Table 4: Electricity Demand Reduction – Total Estimated Statewide Health Co-Benefits from COBRA by County (2021 through 2035)

County	Economic Benefits ($)		Frequency of Health Effects (Top 80% of Occurrences)						
	$ Total Health Benefits(low estimate)	$ Total Health Benefits(high estimate)	Avoided Mortality (low estimate)	Avoided Mortality(high estimate)	Avoided Infant Mortality	Avoided Total Hospital Admits	Avoided Hospital Admits, All Respiratory	Avoided Hospital Admits, Cardiovascular (except heart attacks)	Avoided Work Loss Days
Atlantic	118,850.18	268,233.10	0.01	0.02	0.00	0.00	0.00	0.00	1.16
Bergen	479,980.83	1,081,663.75	0.04	0.10	0.00	0.02	0.01	0.01	5.83
Burlington	216,319.65	487,758.16	0.02	0.04	0.00	0.01	0.01	0.01	2.08
Camden	177,011.91	399,112.76	0.02	0.04	0.00	0.01	0.00	0.00	1.78
Cape May	32,968.60	74,463.68	0.00	0.01	0.00	0.00	0.00	0.00	0.19
Cumberland	36,184.94	81,616.96	0.00	0.01	0.00	0.00	0.00	0.00	0.38
Essex	311,439.34	703,218.41	0.03	0.06	0.00	0.01	0.01	0.01	4.31
Gloucester	271,537.50	615,996.54	0.02	0.06	0.00	0.02	0.01	0.01	2.58
Hudson	131,611.25	295,460.99	0.01	0.03	0.00	0.01	0.00	0.00	2.54
Hunterdon	34,436.23	77,951.52	0.00	0.01	0.00	0.00	0.00	0.00	0.35
Mercer	120,058.29	270,843.51	0.01	0.02	0.00	0.01	0.00	0.00	1.48
Middlesex	608,971.67	1,374,477.97	0.05	0.12	0.00	0.02	0.01	0.01	8.17
Monmouth	325,763.79	735,930.41	0.03	0.07	0.00	0.02	0.01	0.01	3.15
Morris	133,735.95	301,820.07	0.01	0.03	0.00	0.01	0.00	0.00	1.49
Ocean	443,574.82	1,001,498.08	0.04	0.09	0.00	0.02	0.01	0.01	2.90
Passaic	78,981.70	178,052.04	0.01	0.02	0.00	0.00	0.00	0.00	1.05
Salem	20,840.23	47,114.66	0.00	0.00	0.00	0.00	0.00	0.00	0.16
Somerset	97,167.10	218,972.60	0.01	0.02	0.00	0.01	0.00	0.00	1.22
Sussex	37,162.24	83,917.50	0.00	0.01	0.00	0.00	0.00	0.00	0.35
Union	361,623.95	814,544.57	0.03	0.07	0.00	0.01	0.01	0.01	4.86
Warren	22,385.89	50,500.41	0.00	0.00	0.00	0.00	0.00	0.00	0.21

Table 5: Synergistic Energy Integration – Total Estimated Statewide Health Co-Benefits from COBRA by County (2021 through 2035)

County	Economic Benefits ($)		Frequency of Health Indices (Top 80% of Occurrences)						
	$ Total Health Benefits(low estimate)	$ Total Health Benefits(high estimate)	Avoided Mortality (low estimate)	Avoided Mortality(high estimate)	Avoided Infant Mortality	Avoided Total Hospital Admits	Avoided Hospital Admits, All Respiratory	Avoided Hospital Admits, Cardiovascular (except heart attacks)	Avoided Work Loss Days
Atlantic	390,505.92	881,328.12	0.04	0.08	0.00	0.02	0.01	0.01	3.80
Bergen	1,577,068.97	3,553,982.65	0.14	0.32	0.00	0.08	0.04	0.04	19.15
Burlington	710,760.99	1,602,615.72	0.06	0.14	0.00	0.04	0.02	0.02	6.85
Camden	581,608.30	1,311,359.02	0.05	0.12	0.00	0.02	0.01	0.01	5.84
Cape May	108,325.13	244,665.02	0.01	0.02	0.00	0.00	0.00	0.00	0.62
Cumberland	118,893.09	268,168.49	0.01	0.02	0.00	0.01	0.00	0.00	1.23
Essex	1,023,294.65	2,310,543.99	0.09	0.21	0.00	0.04	0.02	0.02	14.16
Gloucester	892,186.42	2,023,946.28	0.08	0.18	0.00	0.06	0.03	0.03	8.46
Hudson	432,435.37	970,792.26	0.04	0.09	0.00	0.03	0.01	0.01	8.34
Hunterdon	113,147.28	256,124.67	0.01	0.02	0.00	0.01	0.00	0.00	1.16
Mercer	394,475.58	889,905.87	0.04	0.08	0.00	0.02	0.01	0.01	4.86
Middlesex	2,000,886.82	4,516,039.51	0.18	0.41	0.00	0.06	0.03	0.03	26.83
Monmouth	1,070,360.83	2,418,026.88	0.10	0.22	0.00	0.05	0.03	0.03	10.34
Morris	439,416.68	991,687.26	0.04	0.09	0.00	0.02	0.01	0.01	4.89
Ocean	1,457,451.44	3,290,592.28	0.13	0.30	0.00	0.06	0.03	0.03	9.54
Passaic	259,510.72	585,025.15	0.02	0.05	0.00	0.01	0.00	0.00	3.45
Salem	68,474.85	154,804.29	0.01	0.01	0.00	0.00	0.00	0.00	0.53
Somerset	319,262.12	719,475.17	0.03	0.06	0.00	0.02	0.01	0.01	4.01
Sussex	122,104.18	275,727.30	0.01	0.02	0.00	0.01	0.00	0.00	1.16
Union	1,188,181.52	2,676,302.50	0.11	0.24	0.00	0.04	0.02	0.02	15.95
Warren	73,553.50	165,929.12	0.01	0.01	0.00	0.00	0.00	0.00	0.67

Limitations, Key Takeaways, and Future Research Directions

While our analysis primarily focuses on optimizing electricity pricing and dispatch, a deeper exploration of the factors influencing consumer prices is essential. Future research should illuminate these intricacies, enhancing affordability and accessibility.

Our operational cost model, proficient in determining least-cost aggregate dispatch decisions, excludes optimal technology investment strategies. Expanding research in this area is vital. Additionally, the potential impact of the Solar Act of 2021 [9] on solar expansion should be integrated into future analyses.

The dynamics of power purchase agreements (PPAs) between generators and utilities, especially in renewable energy, demand further examination. Our analysis, while robust, may not fully capture the significance of market intricacies and price incentives. Prospective research should offer a more comprehensive view of these dynamics.

Our analysis is time-bound, covering up to 2035. Extending this temporal horizon in future research would enable an evaluation of EO 307 and the EMP's long-term implications, aiding in long-range planning and policy formulation.

The *Synergistic Energy Integration* scenario is promising, with substantial emission reductions and health benefits. However, addressing challenges and limitations in its implementation is crucial. This entails assessing economic feasibility, technological requirements, environmental impacts, and equitable distribution of benefits, particularly among underserved communities.

Continual research efforts are imperative to dynamically assess and optimize energy generation pathways in the evolving landscape. Robust analyses of offshore wind grid integration, storage solutions, and demand-side management strategies are essential for addressing reliability and grid stability concerns.

Innovative financing mechanisms and incentive structures should also be explored to accelerate offshore wind project deployment and meet the state's ambitious targets.

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