Sustainability Brief: Energy

Energy science and technology has been a primary driver of human progress for centuries, and intensive energy use is essential to industrialized society. Our energy infrastructure is the foundation that makes almost all commercial activity and modern home life possible. The growth and proliferation of this energy web over the last century has enabled both economic growth and improved quality of life. Along with those advantages and benefits, however, have come increasingly apparent costs, consequences, and risks. Because industrialized civilization depends so heavily on this energy infrastructure, failures or consequences of that infrastructure have a huge impact with economic, social, and environmental implications.

The subject of Sustainable Energy addresses the impacts and vulnerabilities of our energy infrastructure, and focuses on reducing the emerging risks in our current approach so as to ensure the continued availability of reliable, cost-effective energy and the quality of life that depends upon it. These risks include the threat of supply disruptions, economic hardship imposed by rising energy costs, environmental impacts, public health issues, social equity issues, and threats related to either man-made (e.g. terrorist) or natural (e.g. extreme weather) causes, among many others. New Jersey citizens and businesses already bear the costs and consequences of our current energy infrastructure, and these impacts are likely to increase over time.

Ensuring the long term sustainability of New Jersey's energy supply is based on three related actions: a) identifying and acknowledging the consequences and vulnerabilities in the current infrastructure, and characterizing the risks to our quality of life resulting from these factors, b) inventing and commercializing changes to the existing energy architecture, and where necessary, developing entirely new solutions that enhance or displace existing plant or practice, and c) the widespread adoption of these alternative solutions, in sufficient scale to make a difference, and in forms that are both economically and socially acceptable.

These changes are non-trivial and will take decades, and like most of the industrialized world, New Jersey faces both challenges and opportunities in making the transition. This paper provides a summary of key issues related to energy sustainability in New Jersey, and suggests energy sustainability indicators and targets for consideration.

1 Background Information

The scope of New Jersey's sustainable energy challenge is driven by its energy usage profile, along with the current state of its energy infrastructure and practice. Generally speaking, energy usage in the Garden State falls into three broad categories (transportation, heating, and electricity), and depends on supplies both within the state and from outside its borders:

- NJ is a densely populated state with intensive travel activity, and is also the hub of many industrial and commercial operations for which transportation is critical. Transportation is therefore the single largest component of energy use within the state, as well as the primary source of greenhouse gas emissions (about 47%). The overwhelming majority of this energy use is the consumption of gasoline for passenger vehicles, followed by jet fuel in airplanes and diesel in trucks (2009 US DOT). Given the transportation sector's dependence on an essentially sole source of energy (petroleum), it is also highly vulnerable to disruption and globally driven price increases. Overall energy sustainability in NJ means restructuring how energy is used by the transportation sector, and specifically reducing the current dependence on petroleum fuel in favor of more diversified, inexhaustible, and cleaner primary sources that are used with maximum efficiency.

- Electricity is one of the most crucial energy resources within the state, serving all sectors of the economy in many mission-critical applications. The production of electricity accounts for about a third of total energy consumption and the generation base is relatively diversified with about half of in-state generation being nuclear, and the rest predominantly fossil fuel based. Due to this large nuclear component, electricity generation accounts for a relatively modest fraction of the state's carbon footprint (compared with other states) – about 16%. In 2006, the state required almost 21GW of power at peak time, and consumed almost 76 billion kwhrs of electricity during the year. The current supply/demand balance is fragile and under great strain due to global fuel market pressures, aging and in some cases inadequate transmission and distribution systems, and planned retirement of in-state generation plants over the next decade. Long term, NJ faces a real risk of electricity scarcity, lower power quality, disruptive outages, social inequities, and increasing costs, in addition to significant impacts from climate change and other pollution resulting from the generation of electricity from fossil fuels.
- As a heavily populated state in a temperate zone, New Jersey has a significant energy load for space and water heating. Most of the heat is supplied by in-building units consuming either natural gas or fuel oil. This energy application is heavily dependent on fossil fuels as the primary energy source (especially natural gas), representing about 40% of overall New Jersey energy usage. Approximately 37% of the state's carbon footprint is related to the use of fossil fuels for space and water heating.
- Almost all of New Jersey's fossil fuel is imported. There is extensive fuel infrastructure in NJ, however, since it is a primary nexus for national pipelines, as well as home to nationally significant port facilities. Many consumers are already connected to the Natural Gas distribution system, and there are significant opportunities for increased use of (relatively clean) Natural Gas, especially as a bridge technology while more sustainable sources of fuel are developed. About a quarter of New Jersey's electricity is imported from generation assets outside the state, across relatively constrained transmission infrastructure managed as part of the PJM regional grid. NJ's dependence on external sources, both for fossil fuel and for electricity, has become strategically significant, especially as energy demand continues to increase in both US and Global markets. A key factor in considering overall supply mix scenarios is the long planning cycle required for some types of plants, especially those (like nuclear) that imply significant siting issues. Some other types of plant (typically distributed generation assets) can be built more quickly.
- New Jersey is home to an extremely diverse base of properties reflecting its character as one of the oldest, most developed, and heavily populated states in the country. Much of the residential and commercial energy use is on more mature properties where there are significant energy efficiency improvement opportunities. The energy consumption profile is typical of an industrialized population in a temperate zone, including significant air conditioning load in the summer. Electricity consumption

is heavily influenced by peak demand, which is a primary driver of consumer energy cost. Given the need for both heat and electricity at many sites, there is significant opportunity for Combined Heat and Power applications that maximize use of the energy content of the fuel (often efficiency of 80% or more).

- New Jersey has significant renewable energy assets upon which to build its sustainable energy strategy, particularly including solar (both distributed and wholesale grid-supply plants), waste and biomass, and marine resources (offshore wind and wave energy, among other potential solutions). These renewable resources are relatively untapped at the current time, and are large enough to ultimately meet a large fraction (if not all) of NJ's energy requirements. There is limited availability of terrestrial wind resources or large scale geothermal in the state.
- Market structure is another critical factor that shapes New Jersey's energy environment. The energy markets in NJ were formally deregulated in 2009 under the EDECA legislation which, among other things moved electricity generation to a relatively un-regulated, market-based environment. In general, new solutions must achieve market acceptance on a competitive basis with minimal (if any) regulatory support for long term investment surety. The transition to a more sustainable energy infrastructure in NJ is therefore a problem of market transformation.
- Several strategic energy goals have been established for the state. The most striking is the Global Warming Response Act, which is a progressive piece of NJ legislation adopted in 2007. It mandates aggressive reductions in greenhouse gases within the state, including a reduction to 1990 levels by 2020, and a reduction to 80% below 2006 emission levels by 2050. Given that energy use is the primary source of greenhouse gasses (especially methane and CO2), this goal will require massive changes in the current energy infrastructure, and probably implies the nearly complete elimination of the use of fossil fuel within the state for any energy-related purposes by 2050. The state has also completed two recent Energy Master Plans (in 2008 and again in 2011), which establish strategic priorities (in addition to climate change) for energy affordability, reliability and security, and economic development. The framework outlined in this paper builds upon these strategic plans, with a specific goal of achieving a robustly sustainable energy economy by 2050 or earlier.

2 Sustainability Issues (Challenges)

There are several consequences and vulnerabilities associated with the long term operation of the current energy infrastructure. Developing a Sustainable Energy foundation is primarily the process of reducing the risks resulting from our current combination of markets, technologies and physical infrastructure, system architectures, operating practices, participant behaviors, and policies. These risks result from elements of "un-sustainability" embedded in our current approach to energy generation, distribution, and use:

1. **Long Term Fuel Scarcity:** Most of our energy comes from fuels, particularly fossil fuels, which are finite resources on this planet. These resources will eventually exhaust physically, and even now we are forced to tap reserves that are more difficult to reach, more expensive to obtain, and with greater environmental consequence. Fossil fuels will likely become economically and/or politically unsustainable, long before they exhaust physically, resulting in real and enduring risks of fuel (and energy) scarcity.

2. **Reduced Energy Quality:** Our energy supply needs to come from a diverse portfolio of sources (for strategic reasons), minimize dependence on imports over which NJ has little control, and ensure delivery of power that is secure, universally available, and highly reliable. At the current time, we suffer from excessive (in some segments, virtually sole source) dependence on fossil fuels (especially petroleum), heavy dependence on imports for both fuel and electricity, and increasing operational fragility. These risks represent a profound strategic vulnerability, and advancements are needed to insulate our energy infrastructure from market, operational, political, or weather induced disruptions.
3. **Economic Costs:** Energy is a global commodity, and NJ energy pricing is therefore a function of the *global* balance between supply and demand. Prices will increase as fuel reserves are depleted and demand continues to increase, based on both growing population as well as increasing per capital energy use worldwide. Despite some occasional regressions, the long term trend for energy costs in NJ is upward, with base generation costs being further burdened with distribution and peak-related premiums. Energy costs affect everything in the economy, and have economic impacts beyond the cost of energy itself – energy costs (and quality) have a direct effect on many businesses and their economic health and ability to employ New Jersey workers. Not only are energy costs rising, but they are volatile and unpredictable, and beyond the ability of any NJ entity to control.
4. **Climate Change Impacts[1]:** The generation and use of energy is the primary source of greenhouse gas emissions (especially CO2 and methane), and directly drives climate change. The worldwide scientific community has reached an unparalleled consensus that climate change is happening, that it is anthropogenic, and that its consequences are astonishingly large. The impacts of climate change go far beyond the warming of the planet by a few degrees, and include such practical consequences as increased coastal erosion (especially during storm surge) and territory loss, more extreme weather, shifts in agricultural patterns and impacts on food supply, movement of parasites and disease hosts into new territories, and ecosystem die-off and loss of bio-diversity, etc. Recent studies have documented direct human consequences from climate change, including increased mortality rates, forced population migrations, social unrest, health consequences (especially within vulnerable populations), and direct asset losses (especially from weather changes). One recent study estimated economic impacts in the tens of trillions of dollars (globally) from a single climate change effect: the thaw of currently frozen methane reserves. The costs and consequences of climate change are clearly very large, and literally un-calculable looking forward. It is important to note that many of these impacts are already being realized, and will almost certainly grow over the next century, with significant impacts even for the current generation of New Jersey citizens.
5. **Other Emissions and Eco-System Impacts:** The generation, distribution, and use of energy is one of the most environmentally destructive human activities on the planet. Beyond greenhouse gas emissions, there are numerous other discharges including regulated pollutants of both water and air, land impacts from mining (especially coal and hydro-fracking), thermal pollution, and high impact pollutants such as mercury, arsenic, particulates, other heavy metals, etc. These emissions directly impact human health, as well as ecosystem habitats, biodiversity, and related ecosystem factors (ability for natural systems to clean fresh water, erosion from plant loss, etc). Many of these consequences, especially species loss, are irreversible. Our energy economy should not be considered sustainable if it results in the irreparable degradation of the bio-sphere upon which our long term survival depends. For further discussion on the

[1] This paper addresses energy related greenhouse gas emissions, which are a primary driver of climate change. It should be acknowledged that there are non-energy sources of greenhouse gases (cement production, for example), and non-energy related mitigation methods (like re-forestation) that should also be considered but which are beyond the scope of this paper.

sustainability issues surrounding public health, biodiversity and habitat loss and natural systems see the *Sustainability Briefs* on those topics.

6. **Public Health:** For numerous reasons, our energy infrastructure directly affects human health and wellness. On one hand, a strong energy infrastructure supports a healthy human living environment (and comfort) through proper waste management and sanitation, the availability of clean fresh water, improved climate control, medical care, etc. Conversely, failures in the energy system put those critical living supports at risk. Meanwhile, our current approach to energy results in numerous direct threats to public health, including both the climate change and pollutant impacts noted above. Numerous direct impacts, such as mercury in the food chain or chronic respiratory distress across entire populations, have been identified as consequences of fossil fuel incineration. For further discussion on the sustainability issues surrounding public health see the *Sustainability Brief* on this topic.
7. **Social Equity Impacts:** Many of the benefits of our energy economy, and many of the costs and consequences, accrue across society unevenly. Rising energy costs tend to affect working class families more severely, and infrastructure implications (asset siting, pollution, etc.) are more frequently levied on populations that are less able to defend themselves. One clear externality of the current infrastructure (and market structure) is that the benefits (such as cheap electricity) tend to concentrate in more affluent areas, while the consequences (waste, property devaluation, etc.) are frequently distributed "somewhere else" (i.e., out of sight, and out of mind). This disparity can aggravate class tensions and social unrest. While these factors are not pronounced in New Jersey currently, riots motivated by energy austerity and "energy poverty" have become substantial issues in other parts of the world. This is not just an issue of "have vs. have-not" (which is serious), but "cost-bearing vs. not-cost-bearing". Any assessment of sustainability should also include social equity factors, not just for the current environment, but how that might change long term.

Many of these sustainability issues result in significant economic, social, or environmental harm, consequences that can be avoided if the transition to a more sustainable framework can be accomplished. The costs of moving to a more sustainable infrastructure can therefore be balanced with the cost burden of the currently unsustainable framework. It should be emphasized that environmental benefits, although meaningful in their own right, also have profound economic and human benefits as well – sustainable energy is not just about "saving the planet", it is about minimizing human harm.

3 Sustainability Responses (Opportunities)

Just over 10,000 years ago, human civilization made the huge leap from the hunting and gathering of food to the domestication of plants and animals through agriculture. The benefits of more efficient, diversified, and reliable food production provided the foundation for the most profound advancements of civilization. Energy wise, we remain primitive hunter-gatherers, expending a large and scattered effort to scavenge fossil fuels from wherever they are hidden. As we have accomplished through agriculture, we now have the opportunity to "domesticate our energy supplies", transitioning from a finite base of fuels that are increasingly hard to acquire to the use of sustainable energy flows that can be efficiently, reliably, and economically harvested continuously. A transition to sustainable energy fundamentally alters our infrastructure trajectory: consumption of a finite resource (like fossil fuels) increases the cost and risks of that resource, while conversely, increased deployment of sustainability energy technologies decreases their cost and risk, and ultimately the risks and costs to society overall.

There is no single solution that delivers sustainability, and it will take a diverse portfolio of actions and alternatives to make sustainable energy a reality. In some cases, the transition to sustainable energy will require deep and transformative changes in the current infrastructure, not incremental advancements. Considering the unique conditions within New Jersey at the current time, there are five primary pathways for advancing the state's sustainable energy goals.

1. **Use Less:** From a sustainability perspective, the best energy use is no energy use. There is significant potential for an absolute reduction in the amount of energy consumed within the state, in all its forms. These conservation and efficiency improvements impact both heating applications (space and water) and electricity consumption. Peak electricity consumption has multiple impacts on both power quality and cost; improvements can result from real peak reduction (through demand response management solutions, for example) or leveling power balance through storage or generation/usage shifting. Conservation, Efficiency, and Peak Management solutions are among the most mature of sustainable energy technologies, and are the foundation of a sustainable energy infrastructure.
2. **Build A Sustainable Electricity Supply** - New Jersey is blessed with significant in-state renewable energy resources that are relatively untapped. These inexhaustible energy supplies are located within the state, are invulnerable to global market pressures or disruptions, and some are entirely emissions free (once installed). If developed properly, solar, marine, and biomass/waste resources, combined with increased use of co-generation technologies (especially if sustainably fueled) could replace all of the existing fossil fuel generation within the state, and eventually eliminate the need for development of new traditional power plants. By eliminating dependence on increasingly expensive fossil fuels, a renewable generation base will provide a cost effective, and stably priced, source of electricity. Build out of renewable energy infrastructure in NJ will require significant adoption of customer-sited generation (like solar), as well as grid supply connected sources (such as off-shore wind). The aggressive Renewable Portfolio Standard already in place, combined with momentum created through the state's Clean Energy Program, has helped establish a good initial starting point for a fossil-fuel free electricity generation target in 2050. Additional work is needed to sustain this momentum and increase renewable energy development within the state, and there are numerous opportunities to leverage investments already made to increase resiliency and power quality (through storage, for example).
3. **Electrify Transportation[2]** – Petroleum fueled transportation is one of most onerous components of NJ's energy portfolio. Fortunately, supplying cars with their daily energy needs is a highly solvable problem given the emerging availability of electric drive-train vehicles. By fueling vehicles with electricity from the grid rather than petroleum in an IC engine, the transportation segment becomes much more efficient, is founded on a more diversified base of primary energy sources, is insulated from the vulnerabilities inherent in petroleum dependence (including economic risks), and has the potential to be powered renewably (as more renewable generation is incorporated into the grid supply). Practical, economically reasonable vehicles are finally available or on their way to market (at least for some segments), and the primary work to accomplish this high impact sustainability advancement is consumer adoption. Widespread adoption is highly feasible over the next few decades, potentially resulting in a mostly electrically-fueled fleet by 2050. Note that widespread adoption of electric vehicles of all types

[2] A sustainable approach to transportation could/should also include increased use of public transportation, and planning initiatives that encourage workers to live near where they work, along with other changes in work practice and demographics. Those approaches have large potential and are best handled as part of overall sustainability planning. This document focuses on changes in vehicle technology and the associated energy infrastructure impacts.

could also provide resiliency improvements for the residential sector since the car becomes a back-up power provider for the home. Beyond commuter transportation, electric mobility (or other alternative fuel) enhancements are also becoming available for small trucks (natural gas options for the Ford F150, for example), buses, and both short haul and long haul freight.

4. **Alternative Heating Fuels** – Heating for space and water is already relatively efficient (60-80%, compared with 15% for vehicles or 30% for power plants), and is fueled primarily by one of the cleanest fossil fuels (natural gas). Despite those factors, however, it is a large component of the energy portfolio in New Jersey, and a significant fraction of the carbon footprint. Long term, heating of space and water must begin to move away from an almost exclusive dependence on fossil fuels. Short term measures include efficiency and solar water heating, but the primary opportunity for sustainable long term heating is alternative fuels. New Jersey has a key advantage (and opportunity) in that many customers are already connected to a large natural gas supply system - approximately 84% of NJ's residential heating fuel (by energy content) is natural gas, most of which is delivered through an integrated pipeline system. Most of this distribution system is underground, and is therefore relatively immune to extreme weather. By substituting more sustainable sources of natural gas (primarily methane) for the current fossil fuel based sources, heating applications in NJ can be transitioned to a more sustainable basis with minimal end-user involvement. Those heating applications that depend on heating oil can similarly transition to sustainably developed bio-diesel. The primary opportunity for alternative fuels in New Jersey is not transportation (where electricity is the most appropriate fuel), but heating. Significant work is needed to begin development of sustainable sources of methane (and biodiesel), which are likely to depend on waste streams, energy crops, and carbon and heat capture from other processes.
5. **Improving Electrical Infrastructure** - The electric grid today is primarily uni-directional, control is mostly predictive, and consumption points are relatively passive. Sustainable energy requires a grid that is omni-directional, with any point being either a potential generator or consumer, with control systems that are real-time and adaptive. Key drivers will be accommodation of large fractions of the supply coming from intermittent renewable resources, improved reliability and resiliency, more dynamic load balancing, efficient use of diverse sources, and greater market flexibility. Effective grid operation will become more critical as an increasing fraction of private vehicles are electrically fueled.

These five pathways represent the macroscopic mechanisms by which the New Jersey energy infrastructure can evolve from its current form to a more sustainable alternative. These pathways identify high level changes required in the overall energy architecture, but do not prescribe absolute technologies in most cases (e.g., the need to fuel vehicles electrically, without specifying whether that storage is accomplished through batteries or fuel cells). Several of them (efficiency, adoption of electric vehicles, renewable electricity generation) are both highly impactful and relatively feasible today. Some of the pathways (grid infrastructure, alternative fuels for heating) are probably longer term since their potential impact is more nebulous short term, and significant work is required to develop the required technologies and markets. Even in those cases, short term initiatives are worthwhile, particularly in the areas of smart metering and energy storage, since they could have an immediate impact and help shape the development of the pathway overall.

4 Implications

New Jersey faces a unique set of challenges, and a broad matrix of opportunities and responses, as summarized in the sections above. This combination of drivers surfaces several key implications that will shape New Jersey's migration to a sustainable energy economy:

1. **Transition issues:** The energy economy is massive, representing trillions of dollars (globally) in incumbent capital and vested interest. There is an immense inertia in the Business As Usual trajectory, deeply embedded in the behaviors of market participants, technologies and infrastructures, markets, policies and regulations, commercial infrastructure, legal and accounting precedent, and well established practice. Sustainability changes will naturally be resisted, aggressively in some cases, to avoid stranded investment, economic or societal dislocations, or the costs and hassle of change.
2. **Market Transformation:** The existing energy infrastructure is heavily regulated, and depends upon an existing mix of actors with well-established roles and responsibilities. The shift to sustainable energy will require profound changes to that market structure, and a significant evolution in the roles and responsibilities of both existing and new market participants. The incumbent utilities, in particular, are likely to see dramatic changes over the next several decades as their traditional role changes. Proactive policy goals and market development will be critical to ensuring reliable, equitable, and universal access to energy throughout the sustainable energy transition. It should also be noted that these changes will take place not just within New Jersey, but will also depend heavily on regional, federal, and global energy market developments.
3. **Consequences of scale:** Energy systems are exquisitely sensitive to scale, with low-cost only being realized at significant levels of adoption. This is a key issue for emerging new solutions, since even if they are enormously attractive from a sustainability perspective, and may be highly competitive long term *once they reach scale,* their economics and commercial support will suffer in the early stages of commercialization. By comparison, traditional plant and the established infrastructure have already accomplished enormous advantages in scale, as evident in both their cost structure and market presence. This is a fundamental issue that will have a profound effect on how sustainable energy markets mature within the state.
4. **Grid impacts from electric mobility:** It is likely that there will be a massive shift from petroleum fueled vehicles to vehicles electrically fueled via the grid over the next several decades. If all passenger vehicle miles were instantly converted to electricity tomorrow, that would add approximately 20 billion kwhrs of electricity to the current demand, an approximately 26% increase in energy requirement. This transition needs to be considered and planned for proactively.
5. **Need for fair accounting:** Economics is a primary driver of energy markets, and has a large impact on how the system will evolve over time (i.e., which new alternatives are adopted). Particular care is needed to ensure fair accounting of government interventions and subsidies, incorporation of externalities (both costs and benefits), and full life-cycle considerations. Sustainable energy is likely to be more expensive than the perceived cost of energy supplies today (which are artificially low), but less expensive than likely future costs resulting from the currently unsustainable architecture – accounting for that structure properly and fairly is difficult, but will have a large impact on market evolution.
6. **Challenges in forecasting:** One of the biggest challenges in energy planning is that it depends heavily on forward forecasts of numerous factors, and decisions may be highly sensitive to the accuracy of these forecasts. The problem is that many aspects of the energy economy are extremely difficult to forecast with confidence, especially economic factors that depend on future fuel prices. Traditional trade-off and cost/benefit analysis suffers under these conditions, and enlightened methodologies are needed to deal with policy analysis in this highly uncertain environment.

7. **Interplay with other policies:** Energy is such as large domain that it affects many other aspects of our society and infrastructure. There are clear intersections between our energy policies and other aspects of state planning (for example, land use). A comprehensive approach is needed to develop sustainable energy policies in proper context with the rest of the state's strategic goals.
8. **System complexity:** Our energy infrastructure is an exceptionally complex system, encompassing not just technologies, but also human participants, markets, and policies/regulations/legislation. Changes in one part of the system may have subtle but unintended consequences elsewhere in the system, sometimes offsetting the expected impact or, in the worst case, actually making the situation worse. Great caution is needed in evaluating options and prioritizing alternatives to ensure that these more complex interactions and dependencies have been considered to the practical extent possible.
9. **Changing Conditions:** Many aspects of the energy economy are changing quickly, and sustainability planning is therefore an iterative and ongoing process that must continually reassess options and recommended actions based on changing information. In addition, policy decisions need to be based on estimates of long term trends, not just the state of the system at the current time. This challenge is particularly difficult given the long planning horizon associated with most energy assets.

5 Defining & Tracking Sustainability

A sustainable approach to energy addresses the vulnerabilities, consequences, and risks identified above and delivers several key benefits. Our energy economy can be considered "sustainable" when it is:

1. **Clean**: No net generation of greenhouse gases over the full lifecycle of production and consumption, and minimized pollution of air, water, and land. This has profound positive impacts not only on climate change and the ecosystem, but on public health and human wellness as well.
2. **Inexhaustible**: Based on naturally recurring energy flows that don't become scarce as they are used, ensuring continued availability of sufficient amounts of energy for the long term. These renewable sources provide long term invulnerability to physical, political, or economic exhaust of primary supplies.
3. **Safe and Available**: An infrastructure that provides energy where it is needed, when it is needed, and in the amount needed without risk to the population, society, or the environment.
4. **Secure and Reliable**: Energy assets and supplies that minimize dependence on external sources or systems over which NJ has no control, and which reduce vulnerability to physical, economic, or political disruption. Diversity of both supply and infrastructure is strategically essential. A secure infrastructure must address operational factors (e.g. failure under peak load), as well as providing a fortified response to extreme human or nature induced events.
5. **Affordable**: Energy supplies which, when measured on their real total cost to NJ citizens, deliver the above attributes at the lowest possible and most stable cost. Affordability implies maximizing the efficiency of energy use, and minimizing vulnerabilities to external economic, environmental (such as weather) and political influences that can artificially increase costs or make them volatile and unpredictable.

As with other dimensions of sustainability, trade-offs are needed to create a feasible, optimal sustainable energy foundation. When assessing these trade-offs, costs and benefits must capture system-wide externalities which are sometimes difficult to do on an equivalent, or quantitative basis. Essential social equity issues are embedded in many of these trade-offs, since both costs and benefits tend to accrue unequally across society.

To measure and track the sustainability of New Jersey's energy economy, a two tier model is proposed based on primary aggregate indicators that effectively capture the overall progress towards sustainability, and secondary indicators which, where practical to measure, provide more granular visibility.

Primary Indicators: These factors are relatively easy to measure and quantify, and although they are focused on fossil fuel use and greenhouse gas emissions, they implicitly capture many other dimensions of sustainability as well. *This does not intend to imply that reducing fossil fuel use and greenhouse gas reductions are the only aspects of sustainability that matter*, but that these two measures serve as effective aggregate indicators of not just those two goals, but numerous other sustainability factors as well.

1. **Sustainable Supply**: Fraction of the energy supply, measured at the point of primary energy resourcing, which comes from non-fossil fuel sources. The goal by 2050 is to reduce energy related fossil fuel use to zero, and progress is measured as a percentage of that goal accomplished.
2. **Climate Change Impact:** The overall energy related greenhouse gas footprint, measured in tons of CO2 (equivalent) per year. The goal is to reduce energy related greenhouse gas emissions from within the state's borders to 80% below 2006 levels by 2050, and progress is measured as a percentage of that goal accomplished.

Secondary Indicators: These factors may be more difficult to measure in some cases, and may only be possible to quantify on a smaller scale (not statewide). But where these measures are practical they provide more detailed insight on sustainability status or progress:

1. **Waste Fraction**: The fraction of primary energy inputs that are not converted and delivered as useful energy services, which is closely related to overall efficiency. This measure is relatively easy to quantify for most of transportation and electricity usage, but is more difficult for heating applications.
2. **Energy Diversity**: The breadth of primary energy sources used, and the range and redundancy of key infrastructure. The goal is to avoid sole-sources of primary supply, or single points of failure in the system that affect reliability and availability.
3. **Import Independence**: The fraction of energy that comes from in-state sources, and the associated reduction of dependence on imports of both fuel and electricity.
4. **Power Quality:** The fraction of time, throughout the year, that electricity services were not available, or power quality was below target.
5. **Economic Costs:** The overall end-consumer cost for energy, compared with other markets (states, nations) that are attempting to achieve similar levels of sustainability.

6 Conclusions

The energy infrastructure that underpins our industrialized society has a huge impact on our quality of life, and the ability of that way of life to endure in a form that we desire and that our children deserve. Our current energy economy is at great risk due to inherent vulnerabilities and long term consequences resulting from the way we generate, distribute, and use energy in all forms.

New Jersey is faced with a unique blend of challenges and opportunities in addressing the sustainable energy challenge. Five pathways for advancement have been identified at a high level, representing categories of action that can be pursued based on solutions that are both impactful and feasible. Several indicators and targets have been proposed, which can be used to scope the problem, assess and prioritize opportunities, and track progress over time.

Table 1. Preliminary Energy Sustainability Indicators and Targets

Definition	Preliminary Sustainability Indicators	Preliminary Targets	Scale of Analysis	Availability and Period of Data
Primary: The supply portfolio eliminates dependence on finite fuel fossil fuel sources	• Percentage of energy content (BTUs or equivalent), measured at the point of primary source supply, that is not fossil fuel based. .	**Current Status Targets**: •Ratio of non-fossil-fuel supply consumed to total supply consumed, by use (heating, electricity, transportation), including imported electricity. For purposes of this target, bio-fuels may be counted as non-fossil-fuel, but may be discounted based on production method. The goal would be to achieve zero energy-related use of fossil fuels by 2050, in which case the "Sustainable Supply" fraction will be 100% (at the state-wide level). **Forward Looking Target:** • Strength of NJ's enabling legislation and policies relative to the 2050 goal and other states with leading programs. • Accessible market opportunity for non-fossil-fuel sources, considering resource sizing, and regulatory permissiveness of all types. • Relative position of NJ in attracting private investment to non-fossil-fuel solutions.	•State, County, Municipal, and consumer level •State	• Annual • Annual

Definition	Preliminary Sustainability Indicators	Preliminary Targets	Scale of Analysis	Availability and Period of Data
Primary: Energy related greenhouse gas emissions are declining, and on track to meet goals set by the Climate Change Response Act.	• Annual tons of CO2 (equivalent) emissions, estimated bottoms up based on supply mix. • Annual tons of CO2 (equivalent) emissions, based on actual atmospheric measurements, as adjusted to account for the energy-fraction.	**Current Status Target**: • Level of GHG emissions compared with targeted levels, for both estimated and measured targets. The goal would be to achieve a reduction to 1990 levels by 2020 and a reduction to 80% below 2006 emission levels by 2050 (at the state-wide level).	• State, County, Municipal, and consumer level	• Annual or as needed
Secondary: The energy economy maximizes conversion of primary energy content into useful energy services, resulting in the lowest possible waste fraction.	• The fraction of energy that is not converted to useful energy services as intended. •Energy intensity: NJ total and peak energy use per capita, and per unit of economic output (GDP), absolute and trend •Measured efficiency of all in-state power plants •Degree of peak electricity usage, and fraction of energy costs driven by demand charges.	• One minus the ratio of energy delivered as useful energy services (in BTU or equivalent) to the energy content of primary energy sources consumed. The goal would be to achieve the lowest possible waste fraction (i.e., maximum energy efficiency), while recognizing that waste cannot be reduced to absolute zero	• State, County, Municipal, and consumer level. This target may be easier to accomplish for electricity consumption and transportation, but harder to establish for heating applications. May include a combination of measured and estimated factors.	• Annual or as needed
Secondary: There is diversity of primary supplies and no single points of failure in the infrastructure.	• Quantification of supply diversity, based on the number of energy supply types and sources, and relative magnitude of each • A measure of the probability of failure, and the magnitude of impact, of any single points of failure within the infrastructure.	• Avoidance of excessive use of any one source. • Decreased probability of failure and impact of any single points of failure within the infrastructure over time.	• State, County, Municipal, and consumer level • State, County, Municipal, and consumer level	• Annual • Annual

Definition	Preliminary Sustainability Indicators	Preliminary Targets	Scale of Analysis	Availability and Period of Data
Secondary: The state supplies all of its own energy needs, with	• The fraction of energy, fuel and electricity, that comes from sources outside NJ borders.	• Minimized dependence on external sources for either fuel or electricity.	•State	• Annual
Secondary: The infrastructure is able to deliver the energy needed, when and where it is needed, in the quantities needed, at the technical quality required.	• Quantification of the number of failures in delivery or technical quality, and the restoral intervals in the case of outages	• Delivery disruptions are minimized, and when outages occur, the ability to provide at least basic service almost immediately, and full restoral of service as quickly as possible.	• State	• As needed
Secondary: The end-consumer cost of energy is on par with other markets (states, etc.) that are attempting to deliver similar levels of sustainability.	• Cost of energy per unit delivered as perceived on a customer's bill, compared with other benchmark markets with similar goals. • Estimated "all in" cost parameters that more fully consider costs that are not evident on customer bills. • Degree of government support of all types, for each supply source as delivered	• Cost of energy per unit delivered as perceived on a customer's bill, compared with other benchmark markets with similar goals is consistent. • Cost measures properly and fully capture government involvement, externalities, and lifecycle implications..	•Municipal, utility, county, state • Municipal, utility, county, state	• Annual or as needed • Annual or as needed

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