Matter Number 16-00681, In the Matter of the Clean Energy Fund Investment Plan

Clean Energy Fund: Grid Modernization Chapter

Portfolio: Innovation & Research

Submitted by:

The New York State Energy Research and Development Authority

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Clean Energy Fund: Grid Modernization Chapter		
Revision Date	**Description of Changes**	**Revision on Page(s)**
August 1, 2016	Original Issue	Original Issue
June 23, 2017	Power Electronics Manufacturing Consortium: Added initiative High Performing Grid: Tables 7 and 9 have been updated to reflect 2016 actuals, and to provide updated private investment estimates. Milestone 6 has also been updated to correct the stage of NY Prize evaluations referenced.	Multiple
April 19, 2019	As part of the Annual Investment Plan & Performance Report (IPPR) process, NYSERDA has updated budget and benefit values to align with actuals for past years and adjusted budget and benefit forecasts for future years, as appropriate, based on experience to date. Budget and benefit tables have been moved to Appendix B of this chapter and output/outcome tables have been moved to Appendix C of this chapter. Updated rounding convention has been applied to budget and benefit tables.	Multiple
June 15, 2020	As part of the Annual Investment Plan & Performance Report (IPPR) process, NYSERDA has updated budget and benefit values to align with actuals for past years and adjusted budget and benefit forecasts for future years, as appropriate, based on experience to date. The DER Interconnection initiative has been combined with High Performing Grid initiative to form a single market offering. Plan and appendices updated to reflect merger. The Power Electronics Manufacturing Consortium assets and processes have been acquired by CREE Inc. Therefore, the Consortium will no longer operate as a Consortium, no additional partner companies/customers will be added, and it is no longer considered an "active" CEF program.	Multiple
May 7, 2021	As part of the Annual Investment Plan & Performance Report (IPPR) process, NYSERDA has updated budget and benefit values to align with actuals for past years and adjusted budget and benefit forecasts for future years, as appropriate, based on experience to date. The investment plans have been updated to provide a bridge between committed and acquired planning. Committed budget and benefits summaries have been added to plan text, while Appendix B has been updated to reflect expenditure & acquired benefits plans.	Appendix B 11-12, 20-21, Appendix B

Grid Modernization

NYSERDA will focus on enhanced grid visualization (advanced sensing, communications, diagnostics and controls), planning processes and advanced materials that accelerate realization of an advanced, digitally enhanced and dynamically managed "high-performing" electric grid. Initiatives will aim to build the capacity to integrate and dynamically manage loads, clean distributed energy resources (DER), and electric vehicles, thereby lowering the carbon intensity of energy usage and increasing customer engagement in energy markets including enabling the development of community-based energy systems such as microgrids. Such a grid will enable more efficient asset utilization (e.g., reduced operating margins, reduced power demands, reduced energy losses), reduced energy costs, improved reliability and resiliency to climate change induced weather events.

The High Performing Grid initiative will investment in innovation focused on developing a digitally enhanced and dynamically managed or "high-performing" electric grid. This comprehensive initiative moves beyond the singular and less complex question of DER interconnection to include innovation that focuses on dynamically integrating DER into the electric power system. The High Performing Grid initiative was updated in June 2017 to revise the expenditures to reflect 2016 actuals, and to provide updated private investment estimates that consider initial program data, which indicated that the initial projections were greatly underestimating market contributions. Milestone 6 was also updated to reflect that NY Prize Stage 2 evaluations will be used to inform technology gaps, as the Stage 1 evaluations did not provide this information.

The second initiative described in this Chapter is Power Electronics Manufacturing Consortium, NYSERDA is also supporting critical enabling technologies, including improving the efficiency of power electronics, devices that are used for the control and conversion of electric power, and semiconductors more generally.

Program investments and activities will be informed via engagement with stakeholders and subject matter experts.

9.1 High Performing Grid

9.2.1 Overview

Present Situation	• The electric distribution system is operated using older planning tools/algorithms that do not utilize real time data and computational capacities of advanced technologies. Much of the system is operated using relatively passive electro-mechanical devices that do not dynamically communicate with themselves and concern themselves with managing one-way flow of power. • Per the U.S. Department of Energy's (DOE's) Grid Modernization Multi-Year Program Plan (MYPP), "The current business-as-usual trajectory for the electricity industry will not result in a timely transition to a modern grid." Just as the MYPP recognizes a need for additional grid modernization activities, there is a further need for New-York specific research, development, and deployment to accelerate the realization of benefits for all New Yorkers. • Systematic improvements to grid investments and operations are possible at all levels of the grid and are an essential element of the transformation of the grid and related market development envisioned by the Reforming the Energy Vision (REV) initiative. In particular, the adoption of new technologies will: o help maximize the integration of distributed energy resources (DER), including electric vehicles (facilitating de-carbonization of the transportation sector over time) o improve overall system-wide efficiency in electricity delivery and use o enable the development of community-based energy systems such as microgrids, that can improve environmental performance while building energy system resiliency to climate change induced weather-events • As alternatives are developed, validation of technology performance is critical to obtain acceptance by an engineering and standards-based utility culture focused on safety and reliability. Under-utilized and emerging interconnection technologies need to be validated before they will be accepted for use in the electric grid.
Intervention Strategy	• An Innovation Program is envisioned to support and accelerate modernizing NY's electric grid. The overall Grid Modernization Innovation Program is comprised of two investment plans (two Phases), each guided by the goals for reforming the electric system under New York State's clean energy goals. Under the Phase I, DER Interconnection investment plan[1], investments were targeted at technical advances to facilitate interconnection of DER that are currently seeking interconnection in NY. • This investment plan represents Phase II of the Grid Modernization Innovation Program, which targets investments on a broader range of grid modernization topics including innovation in: sensing, communications, controls and diagnostics, advanced materials and dynamic management of the grid and its interconnected elements, notably DER. This phase also advances beyond DER interconnection to pursue full integration of DER's into electric grid operation. In Phase II, the program expects to support innovation in: o sensing, communications, diagnostics and controls that optimizes the coordination of system elements in performing essential system management functions o development of advanced/improved products and materials that address physical asset protection and improved functionality

[1] The DER Interconnection investment plan received approval from the NYS Department of Public Service on May 23, 2016.

	o grid visualization, communication and control systems associated with the interoperability of DER in a manner that can be commonly applied across the utilities and promote consumer-based 3rd party engagement in the energy system that is sought through REV. • For a visual representation of this strategy, please reference the flow chart entitled "Logic Model: High Performing Grid" which can be found in Appendix A.
Goals	• The program will make investments in research that accelerates realization of an advanced, digitally enhanced and dynamically managed electric grid that results in more efficient asset utilization (e.g., reduced operating margins, reduced power demands, reduced energy losses) and improved reliability, and resiliency to climate change induced weather-events. Such investments are also expected to build the capacity to integrate and expand the use of clean distributed energy resources thereby increasing customer engagement in energy markets on a customer-by-customer basis. • Program activity will focus on de-risking technologies by sharing in the costs of developing and testing technologies and new products, demonstrating their value to the utility system and supporting the development of standards for their application. This will enable accelerated adoption and use by utility and non-utility market actors. The program will: o Invest across the full continuum of the innovation chain including research, proof of concept, product engineering, prototyping, modeling/simulation, and field testing. o Develop tools that can be used by multiple market participants to accelerate the build out of a modern and dynamically operated electric grid. o Leverage expertise residing across all innovation programs and apply rigor to all decisions on project funding at all stages in the continuum emphasizing acceleration of technological readiness and commercialization. o Involve stakeholders to the fullest extent practical in the planning and execution of the investment plan. This includes executing efficient mechanisms to sharing learnings with utilities and other critical stakeholders for the purpose of driving adoption.
State Energy Plan/Clean Energy Standard Link	The attributes of an advanced, dynamically managed electric grid are all essential components of any comprehensive strategy to achieve the goals of the New York State Energy Plan, Clean Energy Standard, REV initiative and Climate Leadership and Community Protection Act: • greenhouse gas (GHG) reduction (by integrating clean distributed energy resources and reducing system losses) • improved affordability (by reducing needed capital investment in grid infrastructure) • greater use of clean distributed energy resources, including renewables (by creating a more flexible grid that can better integrate clean DER) • Improved service quality and resiliency (by increased outage avoidance and faster restoration times via advanced fault location, isolation, and service restoration)

9.2.2 Target Market Characterization

Target Market Segment(s)	The target market is electric transmission and distribution systems.
Market Participants	Market participants include:

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Electric utilities (investor-owned(IOU), municipals, cooperatives and authorities)
Grid-technology companies
Medium to large original equipment manufacturers (OEM) with a corporate strategic interest in renewable and/or distributed energy resources
DOE/National Laboratories
Universities and contract research organizations (e.g., Electric Power Research Institute (EPRI))
Large scale renewable resource project developers
DER project developers
Startup companies introducing cutting edge products and services.
New York Independent System Operator (NYISO)/New York Reliability Council
Standards setting committees

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<tr><td>Market Readiness</td><td>

As a result of REV, utility investments in the grid are shifting to more clean, resilient, and affordable energy technologies and solutions which require performance validation to gain acceptance prior to widespread deployment by the utilities. Some of these technologies and solutions are likely common to multiple utilities and therefore offer the opportunity for collaboration to accelerate learnings and ultimately deployment.
New York is home to several leading higher-learning institutions with faculty and curriculum focused on electric power systems and renewable energy. Involvement of these types of institutions can support early stage/proof-of-concept research in smart grid technologies, as well as build workforce capabilities.
The DOE is engaging in similar research, development, and demonstration activities consistent with its Grid Modernization-MYPP. Robust engagement with DOE, additional research institutions, and other leading states in the area of grid modernization will be necessary to promote the setting of reasonable expectations with respect to goals, technology readiness and timing to adoption. Such engagement is also anticipated to result in better leverage of funding.

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<tr><td>Customer Value</td><td>

Full realization of the potential benefits from grid modernization will require investment of large sums of capital over many years. NYSERDA intervention is expected to contribute to acceleration of these investments by de-risking research with utilities and product innovators and through varied technology transfer mechanisms, stimulating changes in public policy and regulation.
Estimates have the benefits from overall grid modernization in New York approaching $13 billion net of around $7 billion in costs. While not all of these benefits will be solely and directly attributed to advances in grid modernization (some will require additional policy interventions such as monetization of environmental externalities), the realization of most of these benefits will be highly correlated with the development and adoption of advanced grid technologies and systems. An example of some of the potential benefits that could be realized through NYSERDA interventions include:

Increased system-wide efficiency could result in a 3-5% reduction in electric delivery system losses or savings of 5-10m tons of carbon over 25 years (at a $20/ton value, benefits could be as high as $0.2 billion over 25 years). This same reduction in electric deliveries produces consumer savings on the order of $40m annually in avoided purchases.
Use of advanced distribution system management tools can improve avoidance of customer outages and facilitate more rapid restoration resulting in customer savings ranging between $1to 2 billion including reduced costs for utilities to respond to major storms.
Nearly 4,000,000 MWH of PV production by 2020 and approximately 2 million tons of GHG reduction annually. If valued at $20/ton this equates to

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	about $40M annually in GHG reductions. Based on a 20-year device life, approx. 40 million tons of reduced GHG is achievable. o Advanced technologies allow existing bulk power system assets to be better utilized increasing system deliverability of clean energy resources on the order of 1,000 MW resulting in reduction of 2m tons of GHG annually. o Cumulative GHG reductions associated with increased renewable energy deliverability measured in tens of millions of tons.

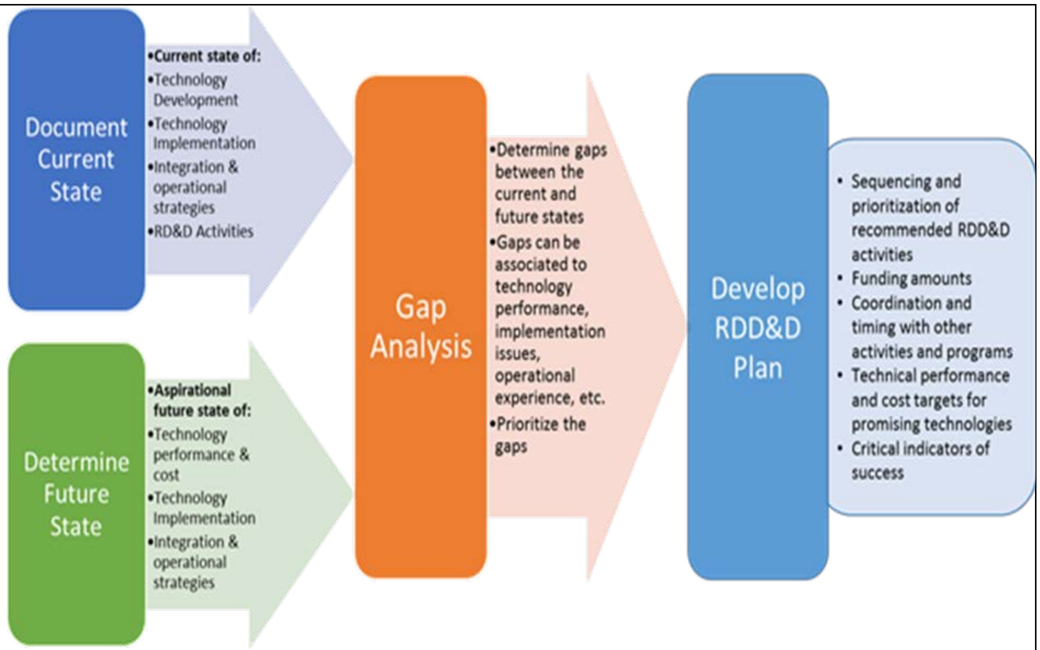
9.2.3 Stakeholder/Market Engagement

Stakeholder/Market Engagement	• Program focus and research activities included within this initiative have been, and will continue to be informed by REV proceedings and participating stakeholder viewpoints. Routine engagement with the New York State Department of Public Service (DPS) will continue to align program focus with current public policy goals. • NYSERDA will participate on working groups and advisory groups organized under the REV proceeding, as necessary, use subject matter experts and consultants to gain insights on gaps in grid innovation and build program offerings that are sharply focused on high priority research. • NYSERDA conducted interviews with utilities and academia in late 2015 and completed a market characterization assessment of it Grid Modernization program in early 2016 using industry expert panelists that provided insight into developing program priorities contained in this plan. NYSERDA has commenced outreach to grid-technology companies to gather intelligence on priority research and will gather additional intelligence on research priorities via direct participation in the formal utility-led Distribution System Implementation Planning (DSIP) stakeholder engagement process, including the Road Mapping project (see Activities below). • NYSERDA will continue to refine an approach for collaboration between NYSERDA, the New York Power Authority (NYPA), DPS, New York utilities, NYISO, and grid tech companies to ensure the Grid Modernization work is compatible with and complimentary to the development of DSIPs, consistent with New York State Public Service Commission (PSC) rules, and focused on needs specific to New York utilities. Collaboration will continue to build mechanisms ensuring various REV (REV Connects), CEF, and other New York State clean energy initiatives are integrated/aligned to make optimal use of time and resources.

9.2.4 Theory of Change

Technology Opportunities and Barriers Addressed	• Achievement of public policy goals for distributed resources and for improving overall electric grid system investment and operating efficiencies is constrained by the lack of real-time intelligence on system conditions, device and integrated system control functions, power quality concerns, and limitations in physical properties of existing system equipment. Validation of technology performance is critical to obtain acceptance by an engineering and standards-based utility culture focused on safety and reliability. These challenges will be addressed by exploring technology development in areas such as, but not limited to, the following: o Research, development, and demonstration of lower cost sensors, higher-speed, lower cost processing of condition monitoring data to facilitate accurate power

	system state estimation, optimized power flow management, and real-time verification and control functions that are essential to multi-party transactions envisioned under REV. o Advancement of high-resolution aerial imaging technologies and advanced diagnostics of weather and other data relevant to outage prediction and recovery operations to accelerate outage predictions, damage assessments and restoration and improve vegetation management practices. o Enhancing the physical properties of materials and advanced engineering of equipment and component systems such as through scaling of superconducting technologies to distribution system applications and developing conductor coatings that mitigate environmental degradation to cable performance to develop more resilient, energy-efficient and higher-performing system components.
Testable Hypotheses	• If real-time data acquisition and computational capacities become commonplace, and DER control technologies meet performance goals, then: o distribution systems could be designed and operated more intelligently and less conservatively, delivering energy more efficiently while maintaining high levels of reliability and increasing resiliency o the capability of determining the optimal locations for, and usable magnitude of DER on the distribution system will no longer be an impediment to increased clean DER and improvements in utilization of the power system. • If research and product development can focus on problems common to all electric utilities, then adoption of innovation can be accelerated. • If capabilities of DOE and federal laboratories (and possibly complimentary in-state laboratory capability currently under development) can be leveraged, then development and adoption of promising grid modernization technologies/practices will be accelerated. • If validation and performance testing is completed, then acceptance of new technology and methods can be accelerated within the engineering and standards-based utility culture focused on safety and reliability.
Activities	***Apply Results of Grid Modernization Roadmap*** – Apply the results of the Grid Modernization Roadmap work, expected to be completed mid-2017 through Phase I of the Grid Modernization Investment Plan (DER Interconnection Investment Plan), to the design of program funding opportunities aimed at developing an advanced, integrated, high-performing grid as follows: • Use gaps assessment to guide program research (priorities/work streams/use cases, budget, and schedule) necessary to accelerate pace of development of technologies, applications and utility capabilities. • Using the assessment, collaborate with NYPA and the utilities, as necessary, on the development of the Advanced Grid Innovation Laboratory for Energy(AGILe) in New York to support grid modernization research that compliments plans and capabilities of the DOE's Grid Modernization Laboratory Consortium Testing Network.



Source (Electric Power Research Institute)

Technology Innovation Funding Opportunities - Provide funding opportunities in support of New York utilities and technology companies to leverage existing capabilities, validate distribution system technologies and practices, create innovative products and applications and otherwise facilitate the development of an advanced high performing integrated electric grid. Begin work as early as 3rd quarter 2016 or as guided by outcomes from the road mapping exercise, voice of customer research, and the DSIP process. This work will compliment, and not be duplicative of, the funding opportunities provided under the Phase I DER Interconnection Investment Plan which focus specifically on facilitating DER interconnection.

- Issue broad competitive solicitations for project proposals across the continuum of technology development (early stage research/ proof of concept, product engineering and testing, and product demonstration).
- Issue requests for proposals (RFPs) or other targeted calls for proposals, potentially in collaboration with New York utilities and DPS, to addresses challenges common across the system (e.g., large smart grid system/REV pilots).
- Specific tech-to-market support will be provided to technology developers to help drive the commercialization of new innovations. Support will be tailored specifically to help early-stage companies navigate the typical channels to market. As applicable, projects will be required to involve no less than one utility; in most cases, multiple utility involvement will be incentivized.

Securing Technical Services Assistance- Issue a solicitation to a field of subject matter experts and/or consultants covering areas of key interest to the program; or leverage applicable expertise acquired through other NYSERDA procurement processes for securing technical assistance to support program activities.

Technology Transfer Mechanisms- Develop more formalized mechanisms (e.g., platforms, periodic workshops, symposia) to transfer best practices/lesson learned from technology development activities. Technology transfer activities will be two-way conduits for information flow thereby providing ongoing "voice of customer" information

	back to the Program. Communicate these use cases to influence policy makers/regulators/utilities on the technical merits of such innovation and the business models such innovation can enable while pushing adoption/uptake by other utilities. Showcase the benefits of advanced grid management systems in managing and enabling increased DER integration using "best-in-class" utility smart grid applications. Begin work in 3rd quarter 2016.
Key Milestones	<u>Milestone 1 (2016) - Complete</u> • Contract with a consultant to conduct a comprehensive analysis of technology gaps and create a roadmap for advancement of the technology and tools necessary to support an advanced, integrated, high-performing grid in New York. <u>Milestone 2 (2016) – Complete</u> • Contract with one or more research/consulting organizations to provide technical knowledge and support for DER interconnection improvements in New York. <u>Milestone 3 (2016) - Complete</u> • Launch a competitive program funding opportunity focused on innovation to reduce DER interconnection burdens in New York State. <u>Milestone 4 (2016) - Complete</u> • Implement a model for collaboration between NYSERDA, NYPA, DPS, NY utilities, and grid tech companies to ensure the Grid Modernization road mapping work is compatible with and complimentary to the development of DSIPs consistent with PSC rules. <u>Milestone 5 (2017) - Complete</u> • Contract with awardees selected under the funding opportunity focused on innovation to reduce DER interconnection burdens in New York State. <u>Milestone 6 (2017) - Complete</u> • Grid Modernization Roadmap complete. <u>Milestone 7 (2017) - Complete</u> • Issue broad competitive solicitation #1 guided by utility DSIP baseline filings and completed stakeholder market research (e.g., demonstrations, product development, engineering analyses and studies) in technology, tools and methods aimed at dynamic management of the electric grid. <u>Milestone 8 (2017) - Complete</u> • Enter into contracts for projects awarded under the broad competitive solicitation #1. <u>Milestone 9 (2017) - Complete</u> • Identify near-term opportunities for applied research that are aligned with utility supplemental DSIPs and the NY Grid Modernization Roadmap. <u>Milestone 10 (2017) - Complete</u> • Issue targeted competitive solicitation #2 guided by utility supplemental DSIPs and the NY Grid Modernization Roadmap. <u>Milestone 11 (2017) - Complete</u> • Enter into contracts for projects awarded under the targeted competitive solicitation #2.

	<u>Milestone 12 (2018) - Complete</u> • Identify technology gaps necessary to support community grid operation based on completed NY Prize Stage 2 evaluations. <u>Milestone 13 (2018) - Complete</u> • Issue broad competitive solicitation #3. <u>Milestone 14 (2018) - Complete</u> • Enter into contracts for projects awarded under the broad competitive solicitation #3. <u>Milestone 15 (2018) - Complete</u> • Issue targeted competitive solicitation #4. <u>Milestone 16 (2019) - Complete</u> • Enter into contracts for projects awarded under the targeted competitive solicitation #4. <u>Milestone 17 (2019) - Complete</u> • Issue broad competitive solicitation #5. <u>Milestone 18 (2019) - Complete</u> • Enter into contracts for projects awarded under the broad competitive solicitation #5. <u>Milestone 19 (</u>2020) - Complete • Issue awards following release of solicitation #6. <u>Milestone 20 (2021)</u> • Issue awards following release of broad competitive solicitation #7. <u>Milestone 21 (2021)</u> • Issue awards following release of targeted competitive solicitation #8. <u>Milestone 22 (2022)</u> • Issue awards following release of broad competitive solicitation #9.

Goals Prior to Exit	• Due to the nature of this work, the long lead time associated with adoption, and society's fundamental need for an efficient and reliable electric grid, NYSERDA envisions continuing to pursue innovation this space for many years. Research priorities will shift as various High Performing Grid functionality are realized and new or improved grid functionalities are identified.
	• By accomplishing the following, NYSERDA aims to accelerate the realization of customer benefits:
	    o Demonstrated capability of advanced technologies, materials, tools and methods to dynamically manage the electric grid through several larger-scale pilot projects and/or through coordinated but disaggregated innovation pilots across the incumbent utilities.
	    o Product development and demonstration projects linked to technology gaps impeding realization of the REV future state and advancing industry standard setting processes to facilitate regulator and industry acceptance, promote support for utility research, development, and demonstration (RD&D) investment and accelerate adoption/application.

	• NYSERDA will exit or cease funding specific areas of technology development and shift focus once scalability is confirmed and a value proposition to customers, regulators and policy makers can be validated/demonstrated.

9.2.5 Relationship to Utility/REV

Utility Role/Coordination Points	• NYSERDA will participate on working groups and advisory groups organized under by the Department of Public Service, as necessary, use subject matter experts and consultants to gain insights on gaps in grid innovation, and build program offerings that are sharply focused on utility-centric, high priority research. • Most program offerings require the engagement/support by at least one utility; NYSERDA funding for product field demonstration or pilot projects almost always require the formal engagement by at least one utility and preferably more. NYSERDA has solid working relationships with each utility, meet regularly with their utility RD&D counterparts and will continue to use this discovery process to design program offerings and technology transfer mechanisms that are of most value to this customer base. NYSERDA expects to develop and implement more effective technology transfer processes collaboratively with the utilities to accelerate technology innovation/adoption (see Activities/Resources). • Program activities will be designed and executed to compliment New York State clean energy goals. NYSERDA will continue to regularly engage with counterparties at DPS for the purposes of program planning and execution with the regulated utilities (see Activities/Resources). DPS will be able to review draft competitive offerings, and participate directly in the evaluation and ranking of proposals for funding to support project investment recommendations that are reasonably aligned with REV and State Energy Plan objectives. • NYSERDA will leverage its activities with those under REV (e.g., REVConnect), and other Innovation program activity (e.g., Building Innovations) to preclude duplication of services making effective use of resources.
Utility Interventions in Target Market	• New York utilities do not have offerings to the market in this area. Furthermore, utilities are a key direct customer of this initiative and therefore are considered part of the target market. • New York utilities currently have modest internally funded research and development activities related to grid modernization. • New York utilities are routinely solicited by vendors looking to test and/or deploy new technology. Much of this new technology is not sufficiently field tested or de-risked to allow for widespread application on the utility grid. • New York utilities participate to varying degrees in broader grid modernization research programs with the DOE (Grid Modernization Lab Consortium) and the EPRI that often are designed to serve a multitude of utility interests across differing jurisdictions and markets; so, unique interests of concern to New York may not be entirely addressed.

9.2.6 Budgets

The commitment budget for all activities included in this investment plan is as follows:

Funding Commitments

Budget	Plan Total	Previously Committed	2020	2021	2022	2023	2024	2025
		------ Commitments Plan ------						
Incentives and Services	-	-	-	-	-	-	-	-
Implementation	3,401,050	1,817,051	580,000	380,000	330,000	230,000	63,999	-
Research and Technology Studies	110,719,233	31,989,735	18,500,475	19,250,000	18,482,850	16,379,660	6,116,513	-
Tools, Training and Replication	2,679,717	2,679,851	(134)	-	-	-	-	-
Business Support	-	-	-	-	-	-	-	-
Total	**116,800,000**	**36,486,637**	**19,080,341**	**19,630,000**	**18,812,850**	**16,609,660**	**6,180,512**	**-**

An annual expenditure budget for all activities included in this investment plan is shown in Appendix B alongside expected acquired benefits. Budgets do not include Administration, Evaluation, or Cost Recovery Fee; these elements are addressed in the Budget Accounting and Benefits chapter filing. The budget as presented in the Budget Accounting and Benefits Chapter will serve as the basis for any subsequent reallocation request. The additional level of detail presented within Appendix B is intended for informational purposes only.

The budget presented in Appendix B cannot be viewed in isolation from planning and regulatory actions that will be undertaken by the utilities and other market actors as the industry transformation called on by REV proceeds. Research priorities are expected to evolve with and be supportive of utility grid modernization plans as such become defined more formally via the REV proceeding. The budget shown in Appendix B is representative of a long-term view of needed investment in grid modernization that is characterized by long-lead times to develop, test and deploy REV enabling technologies. Specific research initiatives and associated costs will be identified and informed by the Roadmap; by needs outlined in the initial DSIPs and biennial updates to the DSIPs; and by progress in rolling out REV-enabling technology. Decisions on research priorities, types of investments, and timing and funding levels will be subject to revision accordingly.

9.2.7 Progress and Performance Metrics

The anticipated commitment benefits totals for the initiative with respect to CEF Order target metrics is as follows:

Benefit Commitments

Direct Benefit (2016-2025)	Plan Total
Energy Efficiency MWh Annual	-
Energy Efficiency MMBtu Annual	-
Renewable Energy MWh Annual	-
CO2e Emission Reduction (metric tons) Lifetime	-
Participant Bill Savings Lifetime	-
Leveraged Funds	420,715,948

Indirect Benefit (2016-2030)	Plan Total
Energy Efficiency MWh Annual	-
Energy Efficiency MMBtu Annual	-
Renewable Energy MWh Annual	-
CO2e Emission Reduction (metric tons) Lifetime	-

Benefits summarized in Appendix B represent the plan for acquiring impacts through completed projects or activities.

Benefits listed as direct, are near term benefits directly associated with this initiative's projects. These benefits will be quantified and reported on a quarterly basis and will be validated through later evaluation. Due to the nature of these activities, estimating energy savings impacts at this stage is difficult because the specific technologies that will be support are not known. However, energy savings for projects supported by this initiative will be tracked and reported.

Appendix C provides program Activity/Output indicators representing measurable, quantifiable direct results of activities undertaken in the initiative. Outputs are a key way of regularly tracking progress, especially in the early stages of an initiative, before broader market changes are measurable. Outcome indicators can encompass near-term through longer-term changes in market conditions expected to result from the activities/outputs of an intervention. Outcome indicators will have a baseline value and progress will be measured periodically through Market Evaluation.

9.2.8 Fuel Neutrality

Fuel Neutrality	• This initiative is not being delivered on a fuel neutral basis.

9.2.9 Performance Monitoring and Evaluation Plans

Performance Monitoring & Evaluation Plan	NYSERDA's approach to monitoring and assessing the effectiveness of the initiative and overall market development is described below. **<u>Test-Measure-Adjust Strategy</u>** • NYSERDA will monitor standard activity/output metrics including number of projects initiated and completed by type, private investment, etc. • For any new technology developments launched under the program, on a yearly basis, NYSERDA staff and contractors will reassess the Technology and Commercialization Readiness Levels for each project in the portfolio. • NYSERDA will conduct peer reviews of certain projects based on need. Examples – technical impasse, pivot point, critical milestone. • NYSERDA will assess the portfolio of projects annually with an advisory panel and with senior NYSERDA management regarding goals, metrics, outputs and outcomes. Where appropriate, evaluation efforts for this initiative may be combined with other NYSERDA evaluation studies to optimize resources where technologies, market actors, strategy or geographical regions overlap. While serving to reduce and mitigate potentially duplicative evaluation efforts, this approach will also reduce uncertainty in evaluation findings where discrete, initiative-level assessments are otherwise difficult to discern due to such overlaps. **<u>Market Evaluation/Impact Evaluation</u>** • Market Evaluation will draw on the logic model and will include baseline and longitudinal measurement of key indicators of market success. • Baseline measurements of key performance indicators will occur within one year of initiative approval and will address key progress indicators such as the technologies/systems available that enable system condition prediction and restoration. In these areas, NYSERDA will first utilize existing information and will fill gaps in information as needed for appropriate baselining. • Regular (e.g., annual or biennial) updates to key performance indicators and measurement of market change will occur once the initiative is

	underway. Sources of data include public and commercially available data, and primary data collection through surveys of key market actors. • NYSERDA will also examine benefits and impacts of product development and demonstration projects.

9.2 Power Electronics Manufacturing Consortium - [Inactive]

9.2.1 Overview

Present Situation	• The field of power electronics has been in a vibrant state of change driven by the introduction of new wide-bandgap[2] semiconductor materials that can operate at higher voltages, frequencies and temperatures. • These materials, including silicon carbide (SiC), have unique properties that, when deployed in a variety of end-use products, can deliver significant performance improvements at the device level, and thus yield more energy savings than their counterparts manufactured on silicon (Si). • These materials are already used in the production of a variety of devices and components and have been for many years. However, existing manufacturing is limited to 3" (75mm) to 4" (100mm) wafers, which are expensive and therefore have limited market adoption. • An important piece of the economic equation for all semiconductor manufacturing involve fabricating on increasingly larger wafer diameters. Such scaling allows for substantial drops in cost, thus driving market adoption. • Given the unique skill sets required to manage the manufacturing on SiC, historically the manufacturing lines (known in the industry as a "fabs") in existence have been "captive" to the device maker, meaning they are not open for use by other device makers. • Part of the market maturation involves the creation of open fabs to support the emergence of new products from new entrants to the market, which in turn fosters greater competition and speeds up market adoption. • To facilitate this maturation, in 2014, the Governor announced the PEMC as an innovative consortium that would leverage industry and government investments to demonstrate the next generation of advanced power electronic semiconductor process capabilities and manufacturing. This is a unique collaboration comprised of GE Global Research working with SUNY Poly CNSE. • The PEMC has established a SiC foundry with equipment capable of manufacturing devices on either 6" (150mm) or 8" (200mm) wafers based on GE's baseline metal-oxide-semiconductor field-effect transistor (MOSFET) flow. This dual wafer size capability enables necessary size scaling for lower cost while mitigating the technical risks of larger wafer availability. • The facility is currently in a prototype phase and PEMC recently celebrated the initial patterning of its first 150mm wafer. This initiative will progress the facility to full production capacity, and will require many additional wafers be run and the process be further developed to qualify the facility for full production. • PEMC is also actively engaging strategic partners to become corporate partners and have the option to use the processing capabilities of the power electronics process line for their own device design, the consortium's baseline MOSFET flow, or a hybrid design.
Intervention Strategy	• This strategy will bring the PEMC facility from its current pilot state to full qualification as a state-of-the-art SiC fab while supporting the consortium's business planning and development activities. It is intended and expected that

[2] "Band Gap" is a physical property of a semi-conductor material that determines, in part, the electrical performance of the material. "Wide band gap" materials (e.g. SiC) typically have higher electrical conductivity and thermal advantages than non-wide band gap materials (e.g. Silicon)

	NYSERDA's investment in PEMC will further encourage funding from additional corporate members and sponsors across multiple disciplines.
	• Funding will be provided to PEMC via the SUNY Research Foundation for:
	  o Converting all the individual tools currently onsite into a fully integrated and operational fabrication facility
	  o Procuring the requisite hardware and software needed to ensure that the facility adheres to the strict quality control standards (ISO-9001 compliance)
	  o Supporting labor costs associated with officially certifying the fabrication line to required industry standards (ACE-Q101)
	  o Developing a business plan for the consortium to reach self-sufficiency

Goals	• Support the establishment of a state-of-the-art production capacity SiC power electronics process line that enables the industry to drive down the costs of technologies implemented with SiC materials and devices, and accelerate time to market and facilitate earlier technology adoption • Continue the engagement of SiC materials, device manufacturers and equipment suppliers and the consortium members in New York State.
State Energy Plan/Clean Energy Standard Link	• The 2015 New York State Energy Plan calls out innovation and research and development (R&D) to "enable New York to accelerate adoption of tomorrow's energy solutions within the State's energy system, while also attracting jobs and investments to New York as a global capital for clean tech." • The Plan also calls on NYSERDA to continue its investments in energy innovation to help reduce greenhouse gas (GHG) emissions, improve energy affordability, system resiliency, and consumer choice. It also recognizes the value of "strategic investments in statewide multi-use assets". • This research and development effort offers significant opportunity to advance the performance and efficiency of a wide variety of power electronics equipment for the power industry in general and specifically for smart grid, advanced buildings, and electric vehicle infrastructure which are key components of the advanced energy system of tomorrow.

9.2.2 Target Market Characterization

Target Market Segment(s)	The target market for this initiative is suppliers of materials, devices and equipment serving renewable energy and electric vehicle power electronics applications.
Market Participants	Market participants include: • Semiconductor related startups and entrepreneurs • Large semiconductor manufacturers • Established corporates that have a strategic focus on semiconductors and/or have a related intellectual property portfolio • Universities that have a known focus on advanced computing, materials science, power electronics, and semiconductors • Established original equipment manufacturers (OEMs) with an interest in new materials and techniques related to semiconductors
Market Readiness	• NY-PEMC is focusing on devices for medium to high voltage power electronics applications where SiC give significant advantages over present Si-based technology.[3]

[3] *Power SiC 2016: Materials, Devices, Modules, and Applications* licensed from Yole Développement

	• Semiconductor devices built upon silicon are approaching performance and size limits. New materials are needed to continue improving these devices. Silicon Carbide materials are an alternative to traditional silicon and offer the potential for much greater performance. These materials have existed as an alternative for approximately20 years, but because of reliability and cost issues they have captured a very small share of the semiconductor market. The total SiC device market is expected to grow rapidly from $200M in 2015 to over $600M in 2021 with a compound annual growth rate (CAGR) of 20%. The CAGR for transistor devices such as the MOSFETS that will be produced in the NY-PEMC facility is expected to be 42% during this period. • Market interest in the continued research and development of SiC materials and their applications is significant. Several very established leaders in the semiconductor industry have expressed interest or have already committed to participating in the PEMC.
Customer Value	• Full implementation and qualification of the 200mm/150mm production line will allow the power electronics industry to achieve or surpass yield and manufacturability indices achieved on the previous 100mm platform. This will drive down the costs of technology implemented with SiC materials and devices, accelerating time to market and enabling earlier technology adoption. • High penetration of SiC technology in medium and high voltage applications has the potential to reduce power conversion loses by over 50% in end-use products such as inverters. Alternative power system designs utilizing SiC devices will also significantly reduce cost and weight of the other components in the system. This will in turn reduce the amount of energy needed to manufacture and transport these devices, providing additional benefits in mobile applications such as electric vehicles by reducing vehicle weight and extending drivable range. • The establishment of a Consortium provides a path for transferring the enabling SiC technology to its members, along with access to billions of dollars' worth of established investments in the Albany NanoTech complex including cleanrooms, analytical and testing services. • The NY-PEMC SiC foundry will support the educational and scientific mission of SUNY Polytech by giving faculty and students access to a commercially relevant, cutting-edge manufacturing facility. • This initiative will also provide an opportunity for regional economic impact through the continued work with industry, infrastructure suppliers, and equipment manufactures in New York.

9.2.3 Stakeholder/Market Engagement

Stakeholder/Market Engagement and Customer Discovery	• NYSERDA, SUNY-POLY, GE have had ongoing engagement with stakeholders along the supply chain for semi-conductor devices. The reaction to the work envisioned has been universally positive and has reinforced the need for this type of work and this intervention. • Significant interest in participation and the resulting work has been expressed by system integrators, original equipment manufacturers, utilities, and other entities that could act both as supplier and customer of innovations developed at the center. • Ongoing stakeholder engagement has been identified as a specific task that will be undertaken as part of this effort, and the expectation is that those already involved will be leveraging their significant relationships with the market participants.

9.2.4 Theory of Change

Technology Opportunities and Barriers Addressed	• **Cost of SiC devices are too high due to wafer size limitations** Currently available SiC transistors made on 100mm or 150mm wafers is up to five times higher than silicon-based transistors. Qualifying and certifying 200mm process equipment will allow for substantial drops in cost, enabling greater market adoption and an associated energy savings. • **SiC manufacturing lines in existence are not open to other device manufacturers.** Management of the manufacturing requires unique skill sets and the cost to establish lines can be prohibitive to new market entrants. Creation of an open fab will support the emergence of new products and increase competition. Connecting the open fab with SUNY Poly will ensure that the facility will stay current with the latest developments in materials research and applied technology.
Testable Hypotheses	• If NYSERDA invests in PEMC, then funding from additional corporate members and sponsors across multiple disciplines will be invested. • If NYSERDA supports the establishment of a state-of-the-art production capacity SiC power electronics process line, then the costs of technology implemented with SiC materials and devices will be reduced, time to market will be accelerated, and earlier technology adoption will be facilitated.
Activities	NYSERDA will contract with the SUNY Research Foundation to advance the PEMC. Upon doing so, NYSERDA will oversee the following PEMC activities: <u>Fab Operations and High-Volume Manufacturing Readiness</u>. Prepare fab infrastructure to support process and module development, device manufacturing, and on technical operations of the SiC fab. • Complete procurement of the necessary spare parts, equipment upgrades or modifications, service and maintenance agreements, and insurance to meet the project objectives. • Complete procurement and setup of the necessary supplies and services, processes gases and chemicals, and other consumables to support process and module development and line qualification. • Operate the line with process and operational discipline for manufacturing, including establishing statistical process control of the equipment and processes. • Monitor and maintain a baseline for surface metal contamination, foreign material, and for critical unit processes supporting the health of the line. <u>Design, Process Startup, and Qualification of the Baseline MOSFET Flow</u>. Plan, execute, and validate the technology transfer of the SiC MOSFET baseline. • Develop and demonstrate a SiC MOSFET process flow with device performance and on-wafer reliability specifications that meet or exceed industry standards. • Provide baseline flow documentation, including: detailed top-down and cross-section schematics with critical dimensions and permissible variation, identified materials, and quantitative metrics of key performance indicators. • Fabricate at least 3 successive batches of SiC MOSFET wafers to demonstrate that the line is ready for qualification. • Provide statistical process control data and in-line test electrical data validating and verifying the baseline.

	Manufacturing Qualification. Implement a quality management system, complete ISO-9001 certification, and complete AEC-Q101 qualification. • Plan and implement a quality management system for the design and manufacture of power electronics devices that meets or exceeds the requirements for ISO-9001 certification. • Stress test the devices until they are shown to meet or exceed the requirements for automotive grade discrete semiconductors. Expand participation in PEMC. Attract partner companies and customers, and sustain fabrication capacity demand required for the fab to be self-sufficient. • Develop a sustainable business plan to produce wafers at a competitive market price, including: mission, vision, structure and membership model, technical strategy, and business and marketing strategy. • Execute on business plan to secure increased participation in PEMC in the form of high value joint development projects and/or capacity allocations for early user hardware or manufacturing of parts.
Key Milestones	Milestone 1 (2017)- Complete • Business plan completed and submitted to NYSERDA for review. Milestone 2 (2018) - Complete • Contract with SUNY Research Foundation for the PEMC. Milestone 3 (2018) - Complete • Production capacity fab infrastructure complete. Milestone 4 (2018) - Complete • Three successive batches of SiC MOSFET wafers fabricated. Milestone 5 (2018) - Complete • Quality management system implemented. Milestone 6 (2018) - Complete • ISO-9001 certification complete. Milestone 7 (2018)- Complete • AEC-Q101 qualification complete.
Goals Prior to Exit	• Complete the design, process startup, and qualification of the baseline SiC MOSFET flow for the SiC fab. • Implement a quality management system, complete ISO-9001 certification for design and manufacture of power electronics devices, and complete AEC-Q101 qualification of the SiC MOSFET device. • Develop the consortium and business model for PEMC, attract partner companies and customers, and sustain fabrication capacity demand required for the fab to be self-sufficient.

9.2.5 Relationship to Utility/REV

Utility Role/Coordination Points	• The innovative devices that will be made possible through the work envisioned at the PEMC will directly contribute towards the ability of utilities to achieve innovation goals under REV and beyond. Power electronics is one application for SiC semi-conductors, and higher

	performance devices will enable a more flexible, responsive, and efficient grid. • As such, utilities will be an important stakeholder involved in the work being completed at the PEMC and it is envisioned that their involvement and contributions will be sought on an ongoing basis. As part of NYSERDA's ongoing role with PEMC, staff will regularly engage utilities to identify performance requirements and other specifications for next generation devices. This intelligence will be provided to PEMC to ensure that the consortium is aware of and working toward meeting utility related requirements. • Once fully operational, PEMC will feature quick-prototyping capabilities. This will enable utilities (and other participating stakeholders) to quickly assess whether newly developed materials and devices will meet identified performance requirements. Given this ability, this should further increase the level of utility coordination and engagement.
Utility Interventions in Target Market	• The New York utilities do not have any similar offering to this market

9.2.6 Budgets

The commitment budget for all activities included in this investment plan is as follows:

Funding Commitments

Budget	Plan Total	Previously Committed	2020	2021	2022	2023	2024	2025
		---------- Commitments Plan ----------						
Incentives and Services	-	-	-	-	-	-	-	-
Implementation	-	-	-	-	-	-	-	-
Research and Technology Studies	16,694,490	16,700,000	(5,510)	-	-	-	-	-
Tools, Training and Replication	-	-	-	-	-	-	-	-
Business Support	-	-	-	-	-	-	-	-
Total	**16,694,490**	**16,700,000**	**(5,510)**	**-**	**-**	**-**	**-**	**-**

An annual expenditure budget for all activities included in this investment plan is shown in Appendix B alongside expected acquired benefits. Budgets do not include Administration, Evaluation, or Cost Recovery Fee; these elements are addressed in the Budget Accounting and Benefits chapter filing. The budget as presented in the Budget Accounting and Benefits Chapter will serve as the basis for any subsequent reallocation request. The additional level of detail presented within Appendix B is intended for informational purposes only. In addition to the budget outlined in Appendix B, $6.3 million in statutory funding is being used to supplement CEF funding for this initiative.

9.2.7 Progress and Performance Metrics

The anticipated commitment benefits totals for the initiative with respect to CEF Order target metrics is as follows:

Benefit Commitments

Direct Benefit (2016-2025)	**Plan Total**
Energy Efficiency MWh Annual	-
Energy Efficiency MMBtu Annual	-
Renewable Energy MWh Annual	-
CO2e Emission Reduction (metric tons) Lifetime	-
Participant Bill Savings Lifetime	-
Leveraged Funds	135,000,000

Indirect Benefit (2016-2030)	**Plan Total**
Energy Efficiency MWh Annual	-
Energy Efficiency MMBtu Annual	-
Renewable Energy MWh Annual	-
CO2e Emission Reduction (metric tons) Lifetime	-

Benefits summarized in Appendix B represent the plan for acquiring impacts through completed projects or activities.

Benefits listed as direct, are near term benefits directly associated with this initiative's projects. These benefits will be quantified and reported on a quarterly basis and will be validated through later evaluation. Due to the nature of these activities, estimating energy savings impacts at this stage is difficult because the specific technologies that will be support are not known. However, energy savings for projects supported by this initiative will be tracked and reported.

Appendix C provides program Activity/Output indicators representing measurable, quantifiable direct results of activities undertaken in the initiative. Outputs are a key way of regularly tracking progress, especially in the early stages of an initiative, before broader market changes are measurable. Outcome indicators can encompass near-term through longer-term changes in market conditions expected to result from the activities/outputs of an intervention. Outcome indicators will have a baseline value and progress will be measured periodically through Market Evaluation.

While the PEMC initiative is being co-funded with CEF and statutory funding, Appendix C indicates the metrics associated with the CEF funding only, which were allocated proportionately to the CEF and statutory budgets being committed.

9.2.8 Fuel Neutrality

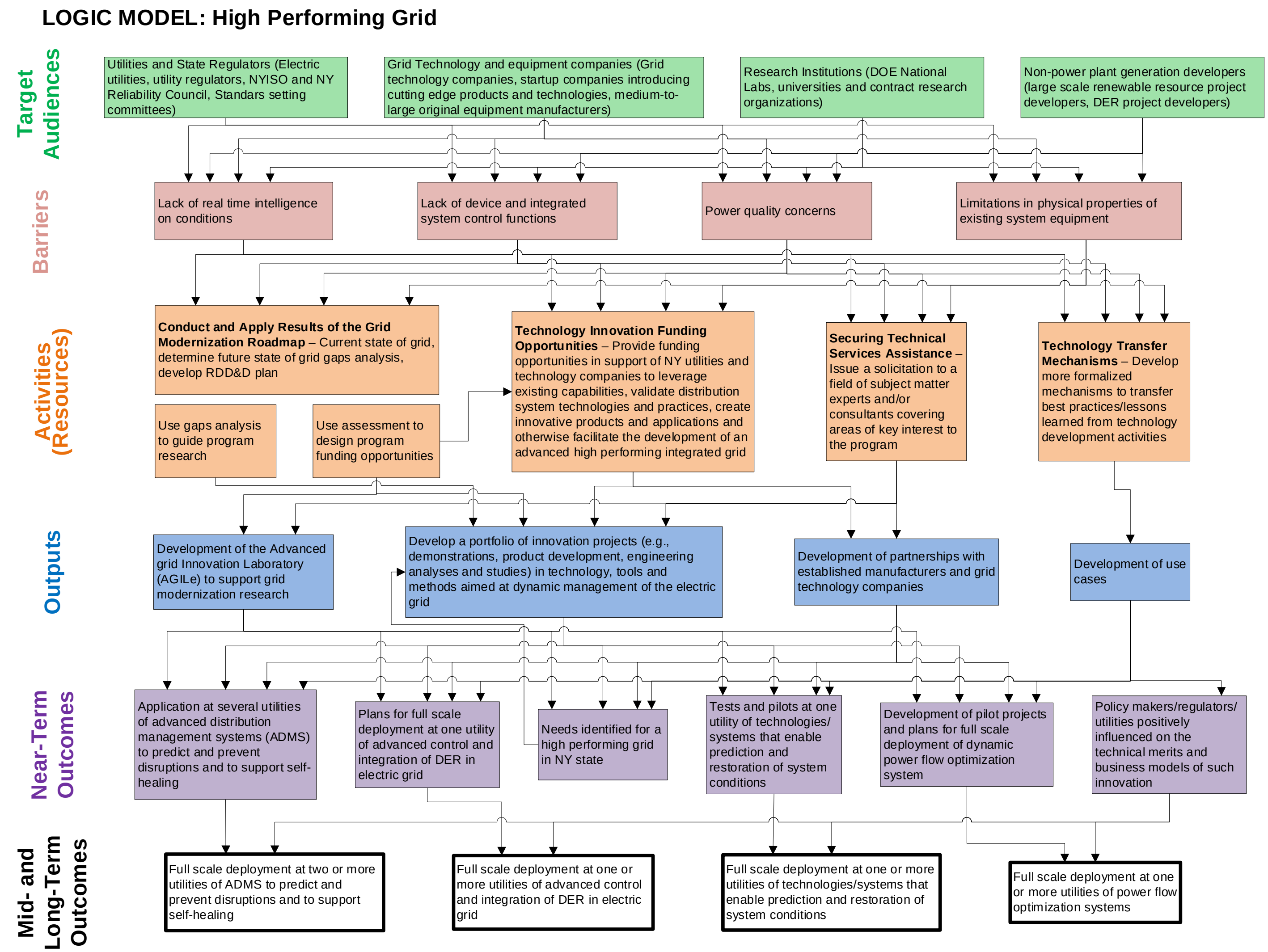
Fuel Neutrality	• This initiative is not being delivered on a fuel neutral basis.

9.2.9 Performance Monitoring and Evaluation Plans

Performance Monitoring & Evaluation Plan	NYSERDA's approach to monitoring and assessing the effectiveness of the initiative and overall market development is described below. **<u>Test-Measure-Adjust Strategy</u>** • Tracking of standard activity metrics including, but not limited to: number of consortium members and number of products commercialized. • In addition, NYSERDA will review progress towards specific contract milestones identified in the PEMC work scope to ensure initiative progresses as planned. Performance toward these contract milestones will be tracked and payments will be made upon completion.

Verified Gross Savings Specification – not applicable

Appendix A – Logic Models



Appendix B | Initiative Budget and Benefits Summary

High Performing Electric Grid

-- Benefits Acquisition Plan --

Direct Benefit	Plan Total	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Energy Efficiency MWh Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Energy Efficiency MWh Lifetime	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Energy Efficiency MMBtu Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Energy Efficiency MMBtu Lifetime	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Energy Efficiency MW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Renewable Energy MWh Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Renewable Energy MWh Lifetime	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Renewable Energy MW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2e Emission Reduction (metric tons) Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2e Emission Reduction (metric tons) Lifetime	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Participant Bill Savings Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Participant Bill Savings Lifetime	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leveraged Funds	420,715,948	-	59,477	482,947	3,982,092	2,702,252	10,250,000	15,400,000	25,600,000	35,600,000	40,600,000	50,500,000	60,500,000	60,400,000	50,468,467	64,170,713

Indirect Benefit	Plan Total	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Energy Efficiency MWh Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Energy Efficiency MMBtu Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Renewable Energy MWh Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Renewable Energy MW Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2e Emission Reduction (metric tons) Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2e Emission Reduction (metric tons) Lifetime	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Energy Usage	Plan Total	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Direct Energy Usage MWh Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Direct Energy Usage MWh Lifetime	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Direct Energy Usage MMBtu Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Direct Energy Usage MMBtu Lifetime	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Indirect Energy Usage MWh Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Indirect Energy Usage MWh Lifetime	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Indirect Energy Usage MMBtu Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Indirect Energy Usage MMBtu Lifetime	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Participants	Plan Total	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Participants	159	-	-	-	-	15	21	25	23	22	15	12	12	10	4	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	**159**	**-**	**-**	**-**	**-**	**15**	**21**	**25**	**23**	**22**	**15**	**12**	**12**	**10**	**4**	**-**

-- Budget Expenditures Plan --

Budget	Plan Total	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Incentives and Services	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Implementation	3,401,050	-	105,453	281,779	410,491	625,000	650,000	500,000	495,000	333,327	-	-	-	-	-	-
Research and Technology Studies	110,719,233	-	824,197	1,900,646	4,578,759	4,812,700	5,480,000	7,653,414	12,887,263	13,544,637	12,109,310	14,289,743	13,055,426	9,791,570	5,307,883	4,483,686
Tools, Training and Replication	2,679,717	400,620	480,183	909,611	533,883	120,000	235,420	-	-	-	-	-	-	-	-	-
Business Support	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	**116,800,000**	**400,620**	**1,409,833**	**3,092,036**	**5,523,134**	**5,557,700**	**6,365,420**	**8,153,414**	**13,382,263**	**13,877,964**	**12,109,310**	**14,289,743**	**13,055,426**	**9,791,570**	**5,307,883**	**4,483,686**

Table Notes:

* With the May 2021 IPPR filing of all investment plans, each Appendix B table that accompanies an investment plan was transitioned from yearly commitment-based budget and benefit plans to plans that forecast expenditures and acquired benefits.

a. Impacts are expressed on an acquired-year basis, and are incremental additions in each year.

b. Historically, this area of investment has had several successful product development-to-commercialization ventures resulting in leveraging private sector funding at 4 or 5 times public sector funding. While it is possible for this to continue into the future, predicting such leverage is speculative; particularly in a capital-intensive industry like the electric utility industry. Companies that can effectively participate in product development in this capital intensive, engineering and standards driven market space are typically well capitalized and have internally developed intellectual property needing only demonstration to the utilities. The leveraging depicted above reflects recent trends in funding a greater share of engineering studies and demonstration projects and less product development projects, biasing the private leverage expectations lower. This mix of projects can change and a single large product development project success could result in greater private sector leverage.

c. The DER investment strategy is focused on facilitating DER interconnection and the nature of the projects anticipated to be undertaken is likely to yield modest direct private investment. Additional indirect private investment is anticipated from increased DER deployment as a result of reduced interconnection burdens.

d. Participants are duplicative (utilities and academia participate concurrently on different projects) so number attempts to identify the number of unique project participants.

Appendix B | Initiative Budget and Benefits Summary

Inactive

Power Electronics Manufacturing Consortium

Benefits Acquisition Plan

Direct Benefit	Plan Total	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Energy Efficiency MWh Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Energy Efficiency MWh Lifetime	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Energy Efficiency MMBtu Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Energy Efficiency MMBtu Lifetime	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Energy Efficiency MW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Renewable Energy MWh Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Renewable Energy MWh Lifetime	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Renewable Energy MW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2e Emission Reduction (metric tons) Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2e Emission Reduction (metric tons) Lifetime	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Participant Bill Savings Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Participant Bill Savings Lifetime	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leveraged Funds	135,000,000	-	-	135,000,000	-	-	-	-	-	-	-	-	-	-	-	-

Indirect Benefit	Plan Total	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Energy Efficiency MWh Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Energy Efficiency MMBtu Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Renewable Energy MWh Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Renewable Energy MW Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2e Emission Reduction (metric tons) Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2e Emission Reduction (metric tons) Lifetime	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Energy Usage	Plan Total	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Direct Energy Usage MWh Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Direct Energy Usage MWh Lifetime	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Direct Energy Usage MMBtu Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Direct Energy Usage MMBtu Lifetime	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Indirect Energy Usage MWh Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Indirect Energy Usage MWh Lifetime	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Indirect Energy Usage MMBtu Annual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Indirect Energy Usage MMBtu Lifetime	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Participants	Plan Total	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Participants	12	-	-	12	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	**12**	**-**	**-**	**12**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Budget Expenditures Plan

Budget	Plan Total	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Incentives and Services	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Implementation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Research and Technology Studies	16,694,490	-	3,322,578	11,304,802	2,072,620	(5,510)	-	-	-	-	-	-	-	-	-	-
Tools, Training and Replication	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Business Support	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	**16,694,490**	**-**	**3,322,578**	**11,304,802**	**2,072,620**	**(5,510)**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Table Notes:

* With the May 2021 IPPR filing of all investment plans, each Appendix B table that accompanies an investment plan was transitioned from yearly commitment-based budget and benefit plans to plans that forecast expenditures and acquired benefits.

a. Impacts are expressed on an acquired-year basis, and are incremental additions in each year.

b. Participants are defined as the number of consortium members.

High Performing Electric Grid

	Indicators	Baseline (Before/Current)	2019 Target (cumulative)	2022 Target (cumulative)
Outputs	Number of studies, demonstrations, and product development projects initiated	0	52	109
	Number of studies, demonstrations, and product development projects completed	0	19	67
	Number of companies supported, utility touchpoints/ partnerships, other partnerships with established manufacturers or grid technology companies	0	31	64
Outcomes	Application of advanced distribution management system (ADMS) to increase system (enterprise level) intelligence by predicting failures, preventing disruptions, and supporting self-healing.	Partial application of ADMS controls in 2 NY utilities	Full application of ADMS controls in 1 NY utility	Full application of ADMS controls in 2+ NY utilites
	Tests and pilots of technologies/systems that enable system conditions prediction and restoration	Early stage products/no pilots	1 product/service in pilot or general use at 1 utility	2+ products/servies in general use at 1 utility
	Application of power flow optimization systems (combination of computer systems and hardware to dynamically manage power flow)	Partial use in 1 utility/planned near-term pilot	1 pilot at 1 utility	Full scale deployment in progress* at 1 utility
	Advanced control/integration of DER in electric grid (ability to monitor and control DER in system, ability to take action on DER resources in system)	Mid-stage research	1 pilot using multiple DER sources	Full scale deployment in progress* at 1+ utility

Table notes

a. A 0 (zero) denotes that the actual value is currently believed to be zero for baseline/market metrics.

b. Full scale deployment in progress means that the utility has presented its rate case to DPS, and is in the process of using that money to deploy power flow optimization systems, DER and intergration systems

Appendix C | Initiative Outputs and Outcomes Summary

Power Electronics Manufacturing Consortium

	Indicators	**Baseline** (Before/Current)	**2019** Target (cumulative)	**2022** Target (cumulative)
Outputs	Number of consortium members	2	12	18
	Number of discrete development projects initiated	0	5	9
Outcomes	In-field demonstrations of devices/systems developed at PEMC	0	3	8
	# of products commercialized	0	5	15
	Revenue for PEMC SiC Process Line	0	$25M	$45M
	Production Capacity	0	4,500	11,000

Table notes

a. A 0 (zero) denotes that the actual value is currently believed to be zero for baseline/market metrics.

b. Development projects refer to development of SiC wafer and subsequent fabrication of full systems and/or projects to pursue new potential applications for SiC materials.

c. Production Capacity refers to the volume of wafers able to be produced at the facility. Full production capacity is expected to be 15,000 wafers per year by 2022, with additional capacity being added as market demand increases.

d. As of Q4 2019 The Power Electronics Manufacturing Consortium assets and processes have been acquired by CREE Inc. Therefore, the Consortium will no longer operate as a Consortium, no additional partner companies/customers will be added, and it is no longer considered an “active” CEF program