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Clean Energy Fund Investment Plan: Building Innovations Chapter

Portfolio: Innovation & Research

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12 Building Innovations

NYSERDA seeks to support the development and demonstrations of new technologies and strategies to enable buildings to be more energy efficient, load flexible and resilient. Buildings are a large user of energy, a major contributor to system peak demand and greenhouse emissions, and an important critical infrastructure for New York State. Activities are designed to engage market participants and the innovation community to create technologies and systems that can enable net zero energy buildings, deep energy efficiency retrofits, and smart buildings – providing value and comfort to occupants and owners.

The broad objectives of the program include:

- Commercialization of advanced building technologies
- Technology validation to drive market impact
- Fostering strategic partnerships between market participants, manufacturers and the innovation community

The first initiative described in this Chapter is the NextGen HVAC initiative, which focuses on heating, cooling and ventilation (HVAC) in buildings. The initiative will focus primarily on improving the performance and validating value propositions in three areas of significant potential: heat and cooling appliances, HVAC controls, and thermal distribution. The goal of the program is to create new economically viable opportunities for energy efficiency in buildings by improving the performance and value propositions of existing and advanced HVAC systems through innovations.

Potential additional initiatives under consideration include Smart Buildings and Deep Energy Retrofits. Smart Buildings have the potential to minimize energy costs, support a robust grid, enable a transactive energy market, increase system resiliency, and facilitate integration of on-site generation and storage. With 80% of existing buildings built before energy codes were established in the late 1970s, New York has the challenge in how to effectively retrofit its stock of older buildings. The Deep Energy Retrofit initiative will look into innovations to offer economically attractive solutions to retrofitting older buildings

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

12.1 **NextGen HVAC**

12.1.1 Overview

Present Situation	• Heating, ventilation, and cooling (HVAC) equipment consumes approximately 40%[1] of the energy used by buildings, making this end use responsible for

[1] US EIA - 2012 Commercial Building Energy Consumption Survey & 2009 Residential Energy Consumption Survey Data

	approximately 25% of the total energy used[2] and 36%[3] of the greenhouse gas (GHG) emissions in New York State. • Cooling requirements for buildings is the primary contributor to the difference between peak utility demand (>32 GW) and typical utility demand (<18 GW). [4] • The large capital investment and long asset life of existing HVAC equipment requires new HVAC technologies to have compelling value propositions in order to achieve market adoption. This is particularly important given the timing of equipment investments, which often occur on a short timeline as emergency equipment replacements. • Due to these market dynamics, investments in research and development to target improvements in efficiency, performance and cost reduction of HVAC technologies is lagging other building technology advancements. • Additionally, solutions on the market today do not uniquely address New York's diverse climate or dense urban population, and are not sufficient to meet New York's aggressive energy and GHG reduction goals. • Focusing on NextGen HVAC equipment innovation will significantly alleviate the stress imposed on the electric grid during the summer months, improving reliability and potentially delaying or avoiding the need for utility distribution system upgrades.
Intervention Strategy	• To encourage private investment in HVAC research and development, NYSERDA will de-risk investments through cost-sharing projects that facilitate the development and commercialization of cutting-edge energy efficient HVAC technologies. • Historically, NYSERDA's building innovation activities have provided support across a wide spectrum of technologies and phases of development. To drive more impact, NYSERDA will focus efforts on high-impact areas and embrace a stronger technology-to-market focus. • The strategy will focus primarily on improving performance and validating value propositions in three areas of significant potential: heating and cooling appliances, HVAC controls, and thermal distribution. • Support will be provided primarily through competitive solicitations for: product development, pilot demonstrations, strategic partnerships, technology-specific challenges, and market coordination. • NYSERDA will identify attributes that will drive HVAC innovation, challenge the innovation/entrepreneur community to develop systems that deliver on those attributes, help establish credibility of new companies and products through engagement and involvement of influential buildings sector stakeholders, and drive market entry through identification and leveraging of existing channels to market for HVAC products and services. • For a visual representation of this strategy, please reference the flow chart entitled "Logic Model: NextGen HVAC," which can be found in Appendix A.
Goals	• The goal of the NextGen HVAC program is to improve the performance and value propositions of advanced HVAC systems, creating new economically viable opportunities for energy efficiency in buildings.

[2] Derived from State Energy Plan and EIA data (40% of 60%)

[3] From 2013 NYS Energy Fast Facts the total NYS GHG emissions is 180 million metric tons. The total emissions associated with HVAC is estimated to be 64 million metric tons (see Appendix) which is 36% of the greenhouse gas (GHG) emissions in New York State.

[4] NYISO Power Trends 2015: Rightsizing the Grid (Figure 5 – Peak vs Average Load). The peak demand in New York State is approximately 32 GW compared to an annual time-averaged demand of 18 GW.

State Energy Plan/Clean Energy Standard Link	• The State Energy Plan identifies buildings as a major user of energy (~60%) and source of GHG emissions in the State. HVAC equipment consumes approximately 40% of the energy used by buildings, making this end use responsible for approximately 25% of the total energy used in New York State. • The State Energy Plan also discusses the need to manage electricity demand to ensure efficient and reliable operation of the grid. The hours of the year when these objectives are most difficult to manage occur during the summer months when space cooling is at highest usage.

12.1.2 Target Market Characterization

Target Market Segment(s)	• While the end use target market segment is all building types, this initiative will target HVAC innovators and manufacturers of technologies that have applications across multiple building types.
Market Participants	Market participants include: • Building-systems-related startups and entrepreneurs • Large original equipment manufacturers (OEMs) with a corporate strategic interest in HVAC technologies and HVAC product manufacturers • Universities with known research activities in HVAC technologies, material science and manufacturing and contract research organizations • Professional Design Societies • National laboratories • Commercial building developers and owners • New York Independent System Operator (NYISO) and Utilities • Established HVAC vendors • Established HVAC contractors • Energy service companies (ESCOs)/energy consultants • System designers • Housing authorities • Builder and trade associations
Market Readiness	• NYSERDA's engagement with building owners and specifiers to-date indicates a need for HVAC solutions currently not being offered by equipment manufacturers. Recent networking events sponsored by NYSERDA for technology developers, building owners and specifiers has shown that owners and specifiers are willing and eager to consider the use of new products that improve the operations of their facilities. • Large equipment manufacturers are typically focused on general market needs where their product development investments have wide geographical application (e.g., all buildings across the nation) and less on specific regional needs (e.g., New York State buildings) where they believe a return on their investment will be more difficult to achieve. However, historically, NYSERDA has been able to inform and influence small to medium technology vendors to develop products focused on State-specific needs. • New York already has a number of small cooling and several heating equipment manufacturers that serve the NYS market, many of whom have expressed interest in product development and commercialization support. NYSERDA has also developed a broad network of contacts and resources that can be leveraged in the HVAC area, including National Laboratories, university researchers, and Centers of Excellence. • Thru past activities NYSERDA is also familiar with a number of large property owners and management companies in NYS that have expressed interest in

	participating in piloting activities to help prove out HVAC equipment value propositions.
Customer Value	• Technology developers receiving awards via this initiative will be able to leverage resources to de-risk investments, gain market insights, and receive customer introductions, thereby increasing sales, reducing time to market, lowering product costs, and creating jobs in NYS • Building owners and management community will gain access to objective third party evaluation of technologies (either as demonstration sites or through case studies), and can provide input with regard to their specific technology needs. • For building owners and management companies, NextGen HVAC solutions will provide compelling value propositions that encompass energy savings (15 to 30% increase in energy savings above current commercial and economically viable HVAC technologies), reduced maintenance, enablement of renewables, load flexibility and improved productivity and health.

12.1.3 Stakeholder/Market Engagement

Stakeholder/Market Engagement and Customer Discovery	• NYSERDA intends to leverage its relationship with established HVAC consortiums and associations that provide a broad range of targeted economic development assistance to small, medium, and large manufacturers and suppliers of thermal and environmental control equipment. • NYSERDA will engage and partner with building owner and manager associations, real estate boards, and other building related associations. • NYSERDA has initiated customer engagement with key stakeholders (including large property managers, architectural engineering firms, building science practitioners, and technology developers) through a series of meetings in NYC and Syracuse to identify and better understand the building owner pain points regarding HVAC in new and existing buildings. Requests for Information (RFIs) will also be used going forward to define technology challenges for the program-established outcomes (see Activities below). • To assist in achieving engagement by various stakeholders, dedicated outreach activities will be initiated to promote program participation.

12.1.4 Theory of Change

Technology Opportunities and Barriers Addressed	• **Centralized HVAC systems have high distribution losses**. Most buildings are heated and cooled using a large central HVAC plant and a distribution system to transfer the thermal energy throughout the building. The current distribution methodology introduces large thermal losses of 9 to 26% affecting overall system performance.[5] Potential innovations to be investigated include: sealing and insulating solutions for distribution systems, "local" on-demand heating and cooling systems (distributed appliances), and novel energy transfer and storage solutions.

[5] Wray, C.P., Diamond, R.C, and Sherman, M.H. 2005. Rationale for Measuring Duct Leakage Flows in Large Commercial Buildings Lawrence Berkeley National Laboratory. LBNL Report 58252.

	• **There is a need for improvements to cold climate heat pumps (CCHPs).** Current air source heat pumps do not perform well in the NYS climate at temperatures below 40F, requiring supplemental electric resistive heating[6,7] Potential innovations to be investigated include: variable speed and multi-stage compressors, turbochargers, hybrid systems, and scaling of the technology for small to medium commercial buildings. • **Energy consumption for air conditioning is dominated by the use of compressors.** The electricity need by compressors can represent more than 80% of total energy consumed by a conventional air conditioning system.[8] A paradigm shift in air conditioning energy efficiency appears achievable if compressor-less cooling approaches can be developed. • **There is a lack of advanced controls for HVAC for small to medium size buildings**. Current HVAC controls for these types of buildings are very basic and limit the opportunity for sustained and additional energy savings through continuous diagnostics and commissioning, and predictive and adaptive controls. Specific opportunities exist for integrated control of hybrid systems consisting of a conventional system, thermal storage, and renewable generation. Advance control capabilities are also expected to optimize renewables and enable participation in demand reduction programs. • **There is a need for integration of renewables/storage with conventional HVAC**. Integration of novel thermal storage solutions with conventional and renewable heating and cooling solutions can significantly improve efficiency and economics as existing storage solutions can be expensive and complex to operate. Integration of renewables/storage with conventional HVAC will also provide demand reduction benefits. • **The coupling of space conditioning and ventilation limits cooling efficiency improvements.** As building envelopes have improved, the sensible cooling requirement has decreased. However, latent cooling requirements, which are largely driven by ventilation needs, have not changed. Lack of solutions for decoupling of the sensible and latent cooling requirements limits opportunities to improve air conditioning efficiency. • **Short duration cooling demand negatively impacts grid reliability and energy bills.** The HVAC industry practice is to size air conditioning equipment to meet peak cooling demands, which occur less than 2% of the time. This practice leads to equipment that operates inefficiently the rest of the time due to "short cycling."
Testable Hypotheses	• If large influential building owners and management companies are involved in program development, then it is more likely that they will participate as demonstration sites and will ultimately accelerate adoption of new innovations. • If building operators are provided with innovations that improve the controllability of HVAC systems, they will then capture unrealized economic value through demand management and/or participation in demand response programs. Pilot demonstrations will be pursued to quantify the site economic value, and when at scale from a market perspective

[6] "Emera Maine – Heat Pump Pilot Program Final Report"; November 17, 2014, EMI Consulting

[7] "Air Conditioners & Cold Climate Air Sourced Heat Pumps"; NYSERDA (internal report), January 15, 2016; Kevin Howley (Intern); Performance and Cost Assessment of Currently Available Air Conditioners and Cold Climate Air Source Heat Pumps.

[8] Unpublished NYSERDA staff analysis using Oak Ridge National Laboratory's Mark VII Heat Pump Model to simulate 36,000 Btu/hr capacity air conditioning system operating at 95 degree F outdoor and 75 degree F indoor conditions.

	• If innovations can enable increased performance with a compelling value proposition from heating and cooling equipment (including thermal distribution systems, integration of renewables and thermal storage), then homeowners, building owners, and building management firms will adopt this equipment to reduce their energy costs.
Activities	• **Determine Technology Performance and Cost Needs.** To operationalize this strategy, RFIs will be issued that seek market intelligence on the specific performance and cost thresholds for various technologies that are likely to drive adoption. Once these targets are well understood, focused competitive "technology challenges" solicitations will be released targeting these thresholds. The solicitations will look to support technology development, technology validation, and tech to market activities. • **HVAC Technology Development**. Solicitations will empower the innovation community to develop solutions that have the ability to provide the desired performance. Multiple innovators may be sought to address a specific technology barrier, increasing the likelihood of a viable/investable solution. Where appropriate, utility involvement will be included. • **Technology Validation Effort**. Demonstration/validation efforts to test the developed, and other available, innovations in the intended relevant operational environment. For this tactic, NYSERDA will directly engage large real estate management organizations and other key stakeholders to serve as test beds. • **Tech to Market Support**. Tech to market support will be provided to technology developers to help drive the commercialization of new innovations. This support will be tailored specifically to help early-stage companies navigate the typical channels to market for buildings technologies; for instance, introductions through planned and structured events with key decision makers (HVAC contractors, architecture and engineering firms, energy service companies, consultants, and building owners/operators).
Key Milestones	<u>Milestone 1 (2016)</u> • Issue RFI, evaluate and establish technology challenge areas and targets. <u>Milestone 2 (2016)</u> • Issue 1st Technology Challenge. <u>Milestone 3 (2017)</u> • Contract projects from 1st Technology Challenge. <u>Milestone 4 (2017)</u> • Review portfolio of activities, solicit market input and reassess technology challenges areas and targets. <u>Milestone 5 (2017)</u> • Issue 2nd Technology Challenge. <u>Milestone 6 (2018)</u> • Contract projects from 2nd Technology Challenge. <u>Milestone 7 (2018)</u> • Review portfolio of activities, benefits to date, solicit market input and reassess technology challenges areas and targets. <u>Milestone 8(2018)</u> • Issue 3rd Technology Challenge.

	Milestone 9 (2019) • Contract projects from 3rd Technology Challenge.
Goals Prior to Exit	• A portfolio of successfully completed projects (i.e., contracts) in a given focus area that establish: o Increased market offerings of non-compressor/non electric cooling technologies o Technology solutions enabling easy integration of renewables and seasonal energy storage into HVAC systems o Improvements in cold climate heat pump (air and ground source) performance o Availability of advanced algorithms, controls, and data analytics capabilities to support optimal commissioning, installation, operation, and maintenance of HVAC systems. • An assessment of the above will be conducted annually with a determination of future activities (continue, pivot or end).[9] • The projected 2030 HVAC end usage is estimated to be 1,315 TBtu of which 267 TBtu will be achievable (economical viable), this leaves 1,048 TBtu as the addressable market for innovations.[10] If the target innovations in NextGen HVAC are successful, an additional 200 TBTUs of economic EE potential could be created. Assuming that 30% of these innovations are adopted in the market by 2030, the program could deliver the following impacts: o An additional 60 TBtu reduction in energy consumption by buildings o 5 million metric tons of CO2 reduction annually o 15 to 30% increase in energy savings above current commercial and economically viable HVAC technologies o 5 - 10% penetration of non-compressor/non-electric based cooling technologies in commercial buildings by 2025, with a demand reduction potential of 500 - 800 MW • A small investment of $3/ton[11] increases the economic potential for GHG reductions by ~ 5M tons.

12.1.5 Relationship to Utility/REV

Utility Role/Coordination Points	• Focusing on development of NextGen HVAC equipment will create the opportunity to improve reliability and potentially delay or avoid the need for utility distribution system upgrades. Similarly, improved controls and capabilities will enable consumers to manage HVAC systems in response to price signals and participate in a transactive energy market envisioned under REV. • To fully realize the benefits of these advances, NYSERDA will engage with the utilities to understand where innovative cooling solutions (peak demand reduction) could provide added value to the distribution system and what performance requirements are necessary.

[9] As product development time may take 2 to 3 years, and measurable impacts may take an additional 3 to 4 years from product commercialization, an accurate assessment of the goals prior to exit may take 5 to 7 years. NYSERDA will monitor market conditions and potential for market impact, and exit a focus area if conditions warrant

[10] NYSERDA Optimal Energy Study 2014

[11] $15 M investment in NextGen HVAC technologies is expected to enable 5M tons GHG economic potential. Note this is not the cost of the measure but the cost associated with enabling the economic potential.-+

	• Utilities could also serve as pilot and demonstration partners to accelerate the time to market of new HVAC technologies. NYSERDA will help to engage utilities as appropriate to help establish these connections. • NYSERDA will partner with utilities to demonstrate the opportunities of aggregation and control of dispersed flexible HVAC systems as an alternative to more expensive distribution system upgrades • NYSERDA will also take advantage of the CEAC Clean Energy Implementation and Coordination Working Group to coordinate planning and implementation with the New York State utilities.
Utility Interventions in Target Market	• Utilities are not supporting end-use buildings research and development. However, utilities are providing a range of incentives for commercially available energy efficient equipment in the target markets, which potentially could be informed by the results of the activities undertaken in this initiative.

12.1.6 Budgets & Expenditures

An annual commitment budget for all activities included in this chapter is shown in Table 1. The annual expenditure projection is included in Table 2. Budgets and expenditures 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 the table below is intended for informational purposes only.

Table 1: Annual Innovation & Research Budget Allocation – Commitment Basis

Commitment Budget	2017	2018	2019	Total
Research and Technology Studies/Development/Demos	$4,000,000	$6,000,000	$5,000,000	$15,000,000
Total	$4,000,000	$6,000,000	$5,000,000	$15,000,000

Table 2: Annual Expenditures Projection

Expenditures	2017	2018	2019	2020	2021	Total
Total	13%	27%	27%	17%	17%	100%

12.1.7 Progress and Performance Metrics

Table 3 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.

Table 2. Initiative Specific Metrics

Indicators[12]		Baseline (Before/Current)	2019 (Cumulative)	2022 (Cumulative)
Activity/Outputs	# of product development projects initiated	0	15	15
	# of product development projects completed	0	6	15
	# of demonstration projects	0	5	10
	# of companies supported or other partnerships (Joint Development, Joint Venture) with established manufacturers	0	20	25
Outcomes	# of products commercialized	0	4	6
	Revenue to companies commercializing products ($millions)	0	$3.0	$18
	# of replications[13] from demonstration projects	0	30	60

In addition to the above outcomes, NYSERDA will also assess the following broad outcomes:

- Demonstrated improvement in economic value proposition of resulting products
- Demonstrated level of kW, Btu, and kWh reduction achieved from developed technologies, demonstrations and replications.

Benefits shown in Table 4 and Table 5 are direct, near term benefits 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 the activities, estimating energy savings impacts at this stage is difficult because the specific technologies that will be supported are not known. However, energy savings for projects supported by this initiative will be tracked and reported.

[12] A 0 (zero) as the baseline value denotes that NYSERDA will not count any activities, outputs, and outcomes supported with prior resources (e.g., pre CEF) towards the achievement of the stated goals in this table.

[13] Here, replications are defined as known incidences where the innovation was deployed without NYSERDA involvement.

Table 3. Direct Impacts

Primary Metrics[14]		2017	2018	2019	TOTAL
Energy Efficiency	MWh Annual				
	MWh Lifetime				
	MMBtu Annual				
	MMBtu Lifetime				
	MW				
Renewable Energy	MWh Annual				
	MWh Lifetime				
	MW				
CO2e Emission Reduction (metric tons) Annual					
CO2e Emission Reduction (metric tons) Lifetime					
Customer Bill Savings Annual ($ million)					
Customer Bill Savings Lifetime ($ million)					
Private Investment ($ million)		20.0	30.0	25.0	75.0

Table 4. Annual Projected Initiative Participation

	2017	2018	2019	2020	Total
Participants[15]	5	8	7	5	25

12.1.8 Fuel Neutrality

Fuel Neutrality	• This initiative anticipates a heavy focus on electric reductions related to cooling and ventilation, however as systems and controls are often integrated, a successful strategy will also support heating aspects.
	• Thirty-six percent (66 M tons) of the State's GHG emissions are associated with the heating, cooling and ventilation in buildings.
	  o Of the total GHG emissions associated with HVAC in buildings 75% is associated with fossil fuel use, only 25% is associated with electricity use, however systems are often integrated.
	  o Improvements in the energy efficiency of fossil fuel driven HVAC technologies are expected to lag that of electric driven technologies. The technical potential therefore is greater for the former.[16]
	• Innovations in natural gas and solar driven thermal technologies (e.g. absorption chillers, hybrid HVAC systems) offer the opportunity for significant reduction in peak demand through permanent load reduction, thereby providing benefits to the grid and electric rate payers more broadly. [17]

[14] Impacts are expressed on a commitment-year basis, and are incremental additions in each year. Totals may not sum due to rounding.

[15] Participants are awardees of NYSERDA contracts to develop or demonstrate NextGen HVAC technologies under this initiative.

[16] Based on the 2030 achievable potential with commercially available technologies for commercial space heating and cooling. Space heating achievable potential is 3% of total 2030 end usage and in commercial buildings is predominantly fossil fuel based. Colling achievable potential is 40% of total 2030 end usage and in commercial buildings is predominantly electric.

[17] "The Future of Air Conditioning for Buildings"; Navigant Consulting and Oak Ridge National Laboratory; July 2016

	• Investing in the development of hybrid HVAC systems that combine renewable technologies together with natural gas driven technologies provide emissions, economic, and resiliency benefits that would not be achievable through an electric-only focused initiative. [18] • Given the significantly large ratio of fossil fuel heating equipment to electric HVAC manufacturers in State, the potential economic benefits to NYS are greater with a fuel neutral strategy.

12.1.9 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>** • Standard metrics: # of projects, leveraged funds, technical/business progress measured via technology readiness level (TRLs) and commercial readiness levels (CRLs). • On a 6 to 8-month interval NYSERDA staff and project participants will reassess the TRLs and CRLs for each project in the portfolio to gauge project progress. • NYSERDA will conduct staged peer reviews of projects at key points. Examples – technical impasse, pivot point, critical milestone. • NYSERDA will assess the portfolio of projects annually with regard to goals, metrics, outputs and outcomes. **<u>NextGen HVAC Strategy M&V</u>** • Technology performance will be measured and verified as part of this strategy. **<u>Market Evaluation</u>** • Market evaluation draws on the theory of change outlined in the logic model and will longitudinal measurement of key indicators of success, such as leveraged funds, products developed and demonstrated, increased revenue, and ultimately replication through increased awareness and technology adoption. • Sources of data include program data, public and commercially available data, and primary data collection through surveys of key market actors. **<u>Impact Evaluation/Field Verification</u>** • A broad demonstration project impact evaluation will include projects from this area and will examine benefits of demonstration projects, rate of and success factors associated with replication, and benefits of replication projects. Cost and energy savings will be quantified as part of this study. • Impact Evaluation will utilize, and verify as needed, data collected as part of this strategy to measure and verify technology performance. Where additional measurement and verification is required, it will be conducted according to IPMVP method(s).

[18] "Exploring the Potential Business Case for Synergies Between Natural Gas and Renewable Energy"; National Renewable Energy Laboratory; February 2014

Appendix A – Logic Model