NYSERDA POWER SYSTEMS PROGRAM AND CLEAN POWER TECHNOLOGY INNOVATION PROGRAM: IMPACT EVALUATION

Final

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Executive Summary

This report presents the results of the impact evaluation of the New York State Energy Research and Development Authority's (NYSERDA's) Clean Power Technology Innovation (CPTI) program, previously known as the Power Systems program. ERS and Industrial Economics, Inc. (the "evaluation team") were selected by NYSERDA to conduct the evaluation. CPTI operated for approximately 10 years, providing over $50 million in funding for a range of clean power technologies. The CPTI program is not offering new funding solicitations; however, NYSERDA is developing a similar program, the Renewable Resource Optimization (RRO) Program, to fund future clean power projects. The RRO program will have a narrower technology focus, primarily for solar photovoltaic (PV), wind, and energy storage research and development (R&D) projects.

Project Overview and Scope

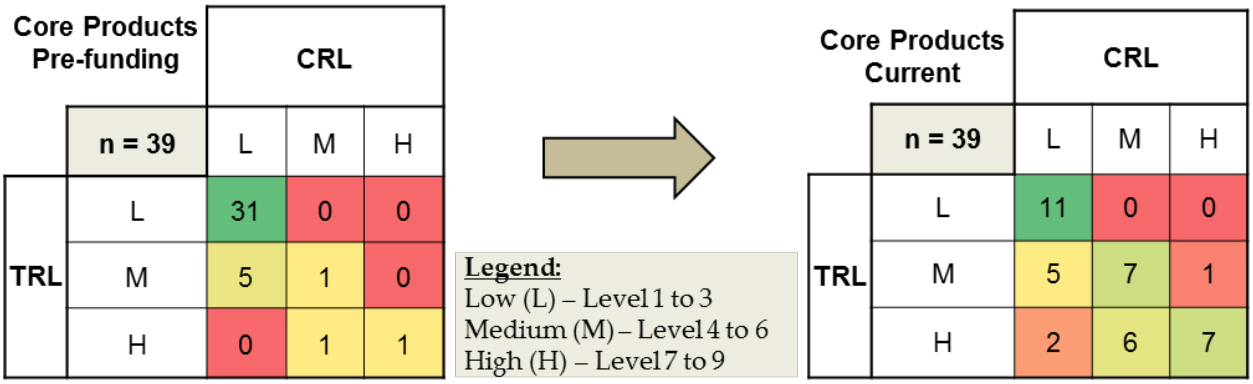
The primary objectives of this evaluation were to document CPTI program achievements and project growth and to identify lessons learned that can be incorporated into the RRO program. The evaluation was divided into two phases. During Phase 1, the evaluation team completed a short review of the contracts funded by CPTI to better understand the scope of funding recipients and to prioritize activities for Phase 2. The Phase 2 work consisted of an in-depth investigation of three Core Product technologies identified during Phase 1: PV, wind, and energy storage. The evaluation team conducted 54 interviews with organizations that received CPTI funding for Core Product technologies to learn about program successes and challenges. Phase 2 also included 19 interviews with a sample of organizations that received funding for the remaining (Non-Core) products, as well as market history interviews with experts in each of the Core Product industries.

Results and Findings

The evaluation team evaluated the maturation of the products funded by the program, as well as the grantees' perceptions of the value of NYSERDA funding, operational activities, and project support. Maturation was assessed using technology readiness level (TRL) and commercial readiness level (CRL) scales in accordance with a calculator provided by NYSERDA. Figure 1-1 presents the TRL and CRL maturation matrices for the Core Products. Nearly 80% of the Core Products were rated low on the TRL and CRL scales when they entered the program, indicating a very early stage of development; by the current assessment, nearly 54% were rated as medium or high on both TRL and CRL scales. Maturation along these scales can be the result of various factors that are internal and/or external to NYSERDA, and many of these products still face significant barriers to commercialization. However, the Core Products on average achieved an average TRL growth of 2.8 and CRL growth of 2.3.

Results differed for each Core Product, with wind products achieving the most growth (average TRL growth of 4.4 and CRL growth of 3.5), followed by energy storage (TRL, 3.2 and CRL, 2.7) and PV (TRL, 1.4 and CRL, 1.1). These differences reflect the state of each of these industries. Wind is the most mature Core Product industry, while PV is slightly less mature and struggles with cheaper foreign competition. Storage is a more nascent industry, and offers opportunities for continued near-term TRL development and a longer-term trajectory for product commercialization.

Figure 1-1. CPTI TRL and CRL Matrices, Pre- and Post-Funding



In addition to TRL and CRL growth, the evaluation revealed the CPTI grantees' perspectives on the value of funding, operation of the program, and role of the NYSERDA project manager. Overall, 85% of the grantees indicated that NYSERDA funding was valuable or essential to the research effort. Regarding program operations, NYSERDA's contracting and administrative requirements of the CPTI program did not present a significant burden for the majority of grant recipients. While the contributions of NYSERDA project managers were perceived as valuable to the overall effort, NYSERDA could provide greater assistance in making additional connections within the clean energy industry.

Recommendations

The evaluation team offers the following recommendations to improve future program offerings and programs:

- **Recommendation 1: Provide strategic funding designed to bridge the gap between R&D and commercialization.** The primary financing gaps faced by emerging clean energy technologies occur during early stage R&D and later pre-commercialization activity. As shown in the TRL/CRL matrices, NYSERDA is effectively deploying financial support for early-stage R&D projects, but more support is needed to help bridge the gap between development and commercial deployment. The commercialization support can often require larger capital investments for product demonstrations combined with extensive business consulting support.
- **Recommendation 2: Prioritize "First Customer" funding for successful technologies.** Many CPTI grantees cited high manufacturing costs as a significant barrier to commercialization. NYSERDA can help mitigate this barrier by offsetting costs to "first customers" and/or by adjusting recoupment terms to include a first customer provision where NYSERDA (or other participating New York State agencies) agrees to purchase or implement successful technologies. This would help accelerate commercialization by conferring credibility to funded technologies and grantee organizations, reducing industry uncertainty and encouraging broader customer adoption of the funded technologies.
- **Recommendation 3: Enhance networking.** The most common suggestion for improvement provided by CPTI interviewees was to increase NYSERDA's role in facilitating industry connections to help grantees expand their networks. NYSERDA's role within the State is well-suited to connect grantees with other industry players, potential supply chain partners, investors, and potential customers. This already happens to some degree, but it was cited consistently as a growth opportunity for NYSERDA, specifically for the Core Products; as the energy storage industry becomes more

mature, NYSERDA can foster relationships between PV and wind generators and the energy storage sector, which has wide applicability across the state and the industry as a whole.

- **Recommendation 4: Hold back 3%–5% of funding for post-grant metrics reporting.** The evaluation team found that NYSERDA's metrics database had an extensive problem of missing data due to under-reporting on the progress of CPTI contracts, making it difficult to accurately quantify the program impacts using reported metrics such as jobs and sales. Only half of the required data was complete in NYSERDA's database for CPTI projects. The missing data resulted in the evaluation team attempting to obtain this information during interviews, but interviewees were not able to provide this data. Incorporating hold-back into future RRO grants, contingent upon submission of complete and accurate post-grant reporting, would facilitate better tracking of progress and would reduce uncertainty in future evaluations.

1 Introduction

ERS and Industrial Economics, Inc., (the "evaluation team") were selected by the New York State Energy Research and Development Authority (NYSERDA) to conduct a two-part evaluation of the Clean Power Technology Innovation (CPTI) program. The CPTI program, previously known as the Power Systems program, operated for approximately 10 years, providing over $50 million in funding for a range of technologies designed to accelerate market adoption of clean power technology systems. NYSERDA is designing a replacement for CPTI, the Renewable Resource Optimization (RRO) program. The purpose of this impact evaluation is to document CPTI program successes and identify lessons learned that can be incorporated into the RRO program design.

1.1 Program Overview

The CPTI program sought to assist New York State innovators in product development of clean power technologies to increase the growth of advanced clean power markets in the State. The program accomplished this by supporting New York businesses and academic institutions in technology development of new and improved clean power generation products, and by addressing the barriers to increased commercialization and market uptake of clean power technologies. Developing a pipeline of clean energy resources is necessary to meet the State's renewable power generation goals, increase grid resiliency, and address the combined threats of climate change and dependency on volatile fossil fuel markets.

The CPTI program was designed to address a wide range of barriers that directly affect the development and application of new clean power products. The primary operational strategy for implementation was through awarded grants based on a competitive solicitation process. The program strategy was to accomplish its goals primarily through the selection process itself, with the following:

- Funding products that would most likely increase the adoption of clean power over time, and
- Improving the business prospects of recipients through grant provisions (such as requirements for partnering, evaluating business strategies of proposers, and offering business assistance through other NYSERDA programs).

While new solicitations will not be offered by NYSERDA for CPTI, NYSERDA is developing the RRO program for a narrower suite of technologies, primarily technology and product development focused on near-term commercialization of photovoltaic (PV), wind, and energy storage technologies. The scope of the team's methodology reflects this narrower future focus, as explained in the subsequent methodology section.

1.2 Evaluation Purpose and Scope

This is the first evaluation of the CPTI program. Given the narrower scope of the RRO program that is replacing CPTI, the primary objectives of this evaluation were to document the CPTI program achievements and product maturation and to identify lessons learned that can be incorporated into the RRO program. The evaluation universe included all products funded by the CPTI program between 2007 and 2015. This includes older products funded under the Power Systems program as well as more recent projects funded under CPTI.

1.3 Evaluation Research Questions

Working in conjunction with NYSERDA, the evaluation team developed a targeted list of research questions to guide the direction of the evaluation. These research questions differ from the questions outlined in the Technology and Market Development (T&MD) Comprehensive Evaluation Plan (CEP) due to subsequent changes in the program and staff priorities, and the desire to make this evaluation as actionable as possible to inform future program changes:

1. Did the program meet its explicit targeted objectives such as the number of awards and magnitude of leveraged funds?
2. Did the interventions move the applicants to the next product development stage as measured by technology readiness level (TRL)/commercialization readiness level (CRL)?
3. How important was the intervention to the ultimate success of each product?
4. What was the broader historical development of select Core Product technologies?
5. To what degree was the broader market (for a Core Product technology) influenced by NYSERDA's intervention?
6. What greenhouse gas (GHG) savings can be directly attributed to the program for portfolio savings claims (largely from demonstration projects)?
7. In hindsight, were there alternative actions the program participants may have taken that would have improved the outcome? What customer actions, funded by the program, were most successful?
8. What is the market trajectory for the RRO target technologies that can be inferred from CPTI? What other technologies may benefit from future program targeting while meeting RRO program goals?

1.4 Report Organization

The remainder of this report is organized as follows:

- Section 2 provides an overview of the methodology for the evaluation activities,
- Section 3 provides the evaluation findings from the team's research,
- Section 4 presents the considerations for future program design for RRO and/or any R&D-focused program offering, and
- Section 5 contains recommendations and conclusions from the evaluation.

2 Methodology

The CPTI evaluation was divided into two phases. Phase 1 was completed in the Spring and Summer of 2016 and served primarily to help the evaluation team better understand the range of technologies funded by CPTI during its 10-year existence. This report represents the culmination of Phase 2, wherein the evaluation team conducted targeted research for a subset of prioritized CPTI grantees. This section presents additional details regarding the structure of each of these phases.

2.1 CPTI Evaluation Phase 1

The primary objective of Phase 1 of the CPTI evaluation was to better understand the contracts awarded throughout the 10-year history of the CPTI program, to focus and refine Phase 2 evaluation activities. The following activities were completed during Phase 1:

- **Desk review of CPTI contracts** – The primary task for Phase 1 was a desk review of the contracts awarded through the CPTI program. The evaluation team targeted a census review of contracts to better understand and categorize the research funded by the program. The evaluation team leveraged NYSERDA's Metrics Database as the system of record for CPTI contract information and worked with the NYSERDA evaluation team to obtain excerpts from additional contract documentation to augment the Metrics Database information.
- **Consolidation of contracts into products** – As part of the desk review, the evaluation team identified 22 companies and/or organizations that received multiple funding awards for the same research from NYSERDA over the course of the CPTI program, as the technologies achieved interim accomplishments. The evaluation team consolidated these CPTI contracts, which represent individual funding instances, into products, which can comprise of multiple funding instances. This consolidation of 126 contracts yielded 94 products as the refined population for Phase 2 research.
- **Initial readiness-level assessment** –TRL and CRL are commonly used in R&D efforts to gauge the development progress throughout a funded research effort. During Phase 1, the evaluation team assessed each product's TRL and CRL at the time of initial NYSERDA funding using a TRL/CRL calculator provided by NYSERDA. These assessments were used as a starting point for comparison with additional TRL/CRL assessments made during the Phase 2 research.
- **Presentation to NYSERDA and identification of Core Product focus** – In June 2016, the evaluation team presented the Phase 1 results, which included descriptive statistics about the CPTI contracts, the results of the consolidation effort, and the initial TRL and CRL scores. During this presentation, the evaluation team proposed an initial scope for Phase 2 activities, highlighting the technology categories containing the majority of program products. These Core Products were PV, wind, storage, and fuel cell projects.

2.2 CPTI Evaluation Phase 2

The objective of Phase 2 was to conduct in-depth research into the Core Products and, to a lesser extent, the Non-Core Products identified during Phase 1 to learn more about the program accomplishments and to identify opportunities for the future RRO program. During the Phase 2 Work Plan, fuel cell products

were removed from the Core Product designation to align with the categories of projects in the proposed scope of the RRO program. The primary activities completed during Phase 2 include the following:

- **Core Product interviews** – The evaluation team conducted in-depth interviews with recipients of NYSERDA CPTI grant funding for the three Core Product categories: PV, wind, and storage. These interviews sought to understand company motivations for pursuing funding, funding recipients' perspectives on the CPTI program, and opportunities to improve the NYSERDA offering for future programs. The interview guide included a series of questions to assess the *current* TRL and CRL of their product and the maturity level *prior to* receiving CPTI funding. The evaluation team attempted to interview a census of grantees developing Core Products (51 total products), and were able to conduct at least one interview for 76% (39) of the Core Products. The full interview results are presented below in Table 2-1. The Core Product interview guide is included as Appendix A.
- **Non-Core Product interviews –** In addition to the detailed Core Product interviews, the evaluation team also conducted shorter interviews with a sample of the remaining Non-Core Products. These products cover a wide range of technologies funded by the program. The objectives of these interviews were to confirm the product data obtained through the Phase 1 desk review, as well as to capture additional data regarding CPTI program successes and opportunities for improvement. The evaluation team conducted Non-Core interviews for 19 products; the product categories are provided in Table 2-2. The Non-Core interview guide is included as Appendix B.
- **Core Product market history interviews and research** – For each of the three Core Product categories – PV, wind, and storage – the evaluation team completed additional research to assess how well NYSERDA's products reflect trends in the broader industry. This task included some background research but primarily consisted of in-depth interviews with industry experts for each Core Product category. The evaluation team recruited industry experts with significant experience in each technology, representing both the public and private sector within and beyond New York. The experts reflected a diversity of experiences; solar PV experts had a wealth of PV R&D experience in many of the same topics addressed by the CPTI program, wind experts represented turbine startups and advocacy organizations, and storage experts had a mix of experience in transportation, grid-scale storage, and batteries. During these interviews, the evaluation team presented a summary of products funded by NYSERDA and solicited the experts' perspectives on the categories and timeline of the funding. The experts were also asked about future opportunities for NYSERDA to help further develop the core product categories.
- **Analysis and summary assessment of findings** – The evaluation team analyzed the trajectory of each funded product based on the product-specific research, market history research, and interviews. CPTI program-level and Core Product findings are presented in Section 3 of this report. Using the same TRL and CRL scales, the evaluation team reviewed the interviewee assessments using product documentation and descriptions, interview responses regarding CPTI-funded activities, and product development activities prior to and subsequent to CPTI funding. The team assessed the updated TRL and CRL scores that reflected progress made through the later date of either the end of NYSERDA-funded research or the date of the interview.

Table 2-1. Phase 2 Interview Summary

Product Category	Total Products	At Least 1 Interview	Total Number of Interviews	Unable to Reach	Market History Interviews (Target 3–5)
Photovoltaics	19	16	25	2	3
Wind	16	11	16	5	5
Storage	16	12	13	4	5
Non-Core	43	19	19	12	N/A
Totals	**94**	**58**	**73**	**23**	**13**

Table 2-2. CPTI Phase 2 Non-Core Product Interview Summary

Technology	Total Products	Completed Interview(s)
Fuel Cell	12	3
Hydropower	5	4
Combustion Turbine	3	1
Power Conversion Devices	3	1
Biomass	2	1
Micro CHP	2	1
Waste Heat	2	1
Anaerobic Digester	2	0
Compressed Air	1	1
Controls/Sensors	1	1
Heating, Ventilation, & Air Conditioning	1	1
Solar Thermal Electric	1	1
Transmission	1	1
TAM Ceramics	1	1
Inertial CO_2 Extraction	1	1
Marine	1	0
On-Road	1	0
Solar and Storage	1	0
Regenerative Drive Elevator	1	0
Repurpose ConEd Hudson	1	0
Totals	**43**	**19**

3 Evaluation Findings

This section presents the evaluation team's findings from the Core Product, Non-Core Product, and market history interviews. These findings reflect the team's research into the maturation of the products funded by the program, as well as grantees' perceptions of the value of NYSERDA funding, operation of the program, and project support. Findings from in-depth interviews with market history experts regarding program funding and future opportunities are also presented for each of the three Core Product categories.

3.1 NYSERDA Program Management

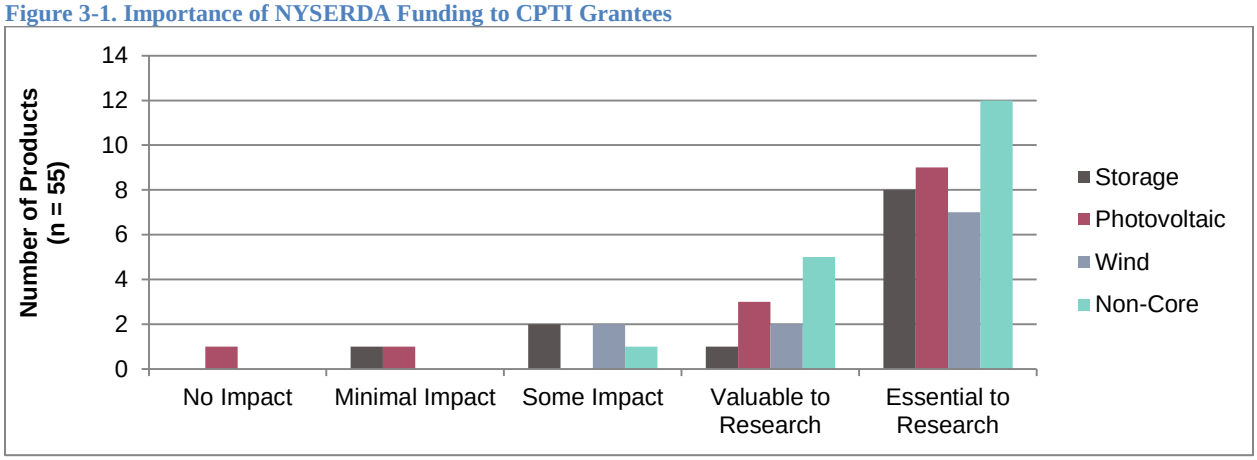
This section explores several aspects of NYSERDA's CPTI program management, including the value of NYSERDA's funding, the effectiveness of NYSERDA's operations, and the role of NYSERDA project managers in supporting CPTI grantees.

3.1.1 Importance of NYSERDA Funding

Asked about the importance and value of NYSERDA funding for development of their product, the majority of interviewees indicated that NYSERDA CPTI funding played a crucial role in product development. As shown in Figure 3-1, 47 out of 55 (85%) respondents rated NYSERDA's funding as either valuable or essential to their research. 69% of interviewees also indicated receipt of funding from at least one other source in addition to NYSERDA. Such funding sources include, but are not limited to, the Department of Energy (DOE), Defense Advanced Research Projects Agency (DARPA), National Science Foundation (NSF), Small Business Innovation Research (SBIR), Electric Power Research Institute (EPRI), and New York Power Authority (NYPA), as well as various private funding entities and/or venture capitalists. Importantly, 85% of the respondents indicated that at least 80% of their program funding was applied within the State; this suggests that NYSERDA CPTI funding is being leveraged for in-state R&D activities.

> *"Without NYSERDA funding, we would have moved to another state where we still have some of our R&D operations. NYSERDA funding kept us in NY."*
> – Photovoltaic product grantee

Figure 3-1. Importance of NYSERDA Funding to CPTI Grantees



3.1.2 NYSERDA Operations

"NYSERDA was friendly and helpful."
"NYSERDA was the easiest to work with out of any government agency."
— Non-Core Product grantees

The interview guide included questions about the impact of NYSERDA operations – primarily the administrative requirements and contracting process on CPTI funded R&D. As shown in Figure 3-2 and Figure 3-3, the majority of CPTI interviewees felt that the NYSERDA contracting process and administrative requirements, respectively, did not hinder project development. Specifically, 84% of the respondents felt that the administrative requirements, such as regularly scheduled check-ins or monthly reports, created minimal burden, and 70% of the respondents experienced little to no burden from NYSERDA's contracting process. NYSERDA operational burdens were slightly more pronounced for energy storage products. As a less mature, more rapidly evolving industry than PV and wind, energy storage companies were on average smaller and also more heavily reliant on NYSERDA funding. The impact of delays between award notification and funding disbursement placed greater pressure on the day-to-day operations for a subset of energy storage products.

Figure 3-2. CPTI Grantees' Perception of NYSERDA CPTI Administrative Burden

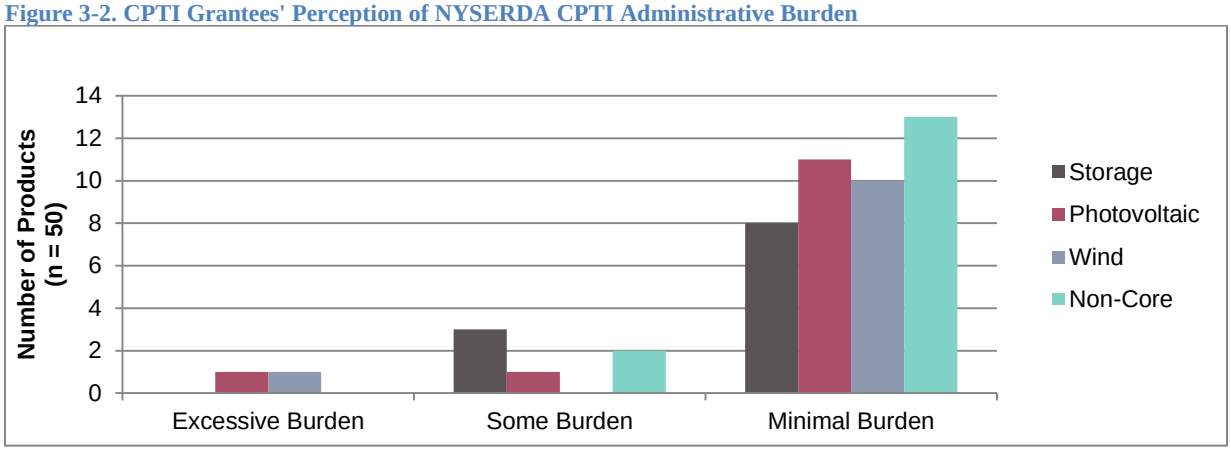
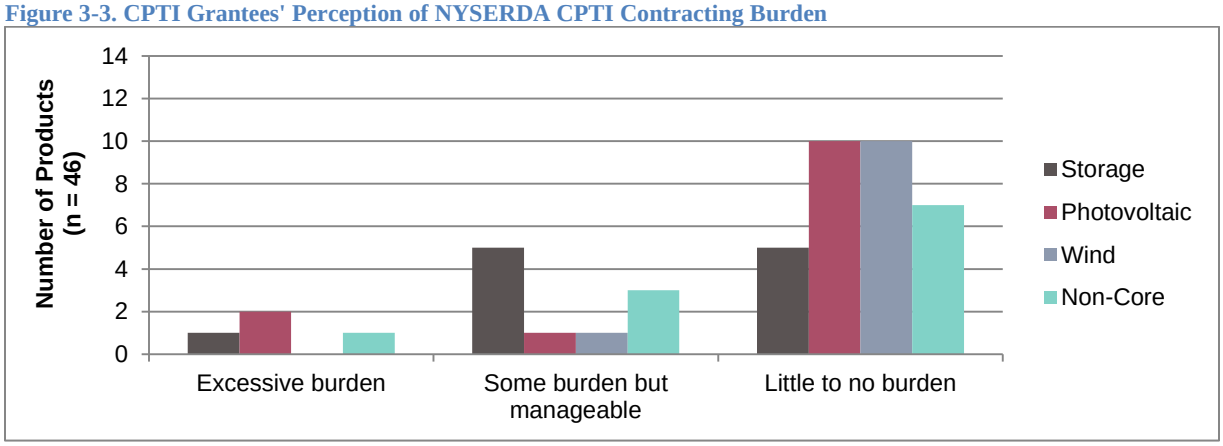


Figure 3-3. CPTI Grantees' Perception of NYSERDA CPTI Contracting Burden



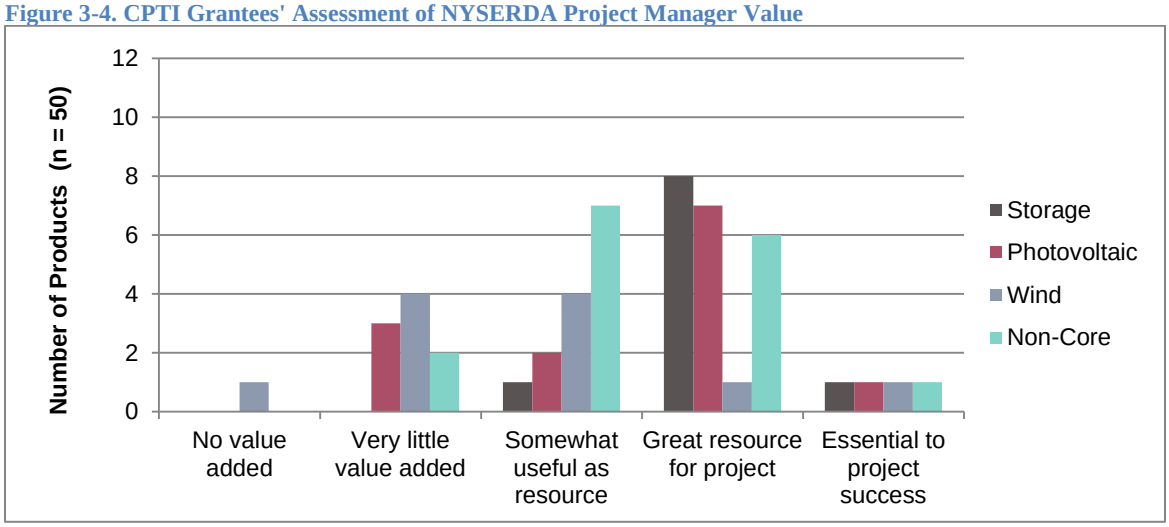
3.1.3 Impact of NYSERDA Project Manager

As illustrated in Figure 3-4, the majority (80%) of interviewees found great value in their NYSERDA project manager. Eleven interviewees found NYSERDA project managers particularly helpful in developing realistic goals and establishing metrics to guide grantees throughout the grant period. One of the more common types of project manager value identified by interviewees was connecting grantees with appropriate licensing and permitting resources across the State.

Of the 50 interviewees that shared feedback on the project manager, nine said that the NYSERDA project manager provided little value added and one interviewee said that the NYSERDA project manager added no value to the product research. Based on further discussion with NYSERDA as to possible reasons for negative results, there were periods of time where NYSERDA had staff turnover, increasing workloads and limiting availability of remaining project managers. Among those interviewees with negative opinions of NYSERDA project managers, feedback included:

- More experienced staff to help overcome technical road blocks and market challenges;
- Foster stronger industry connection; and
- Greater individual project-specific attention and support.

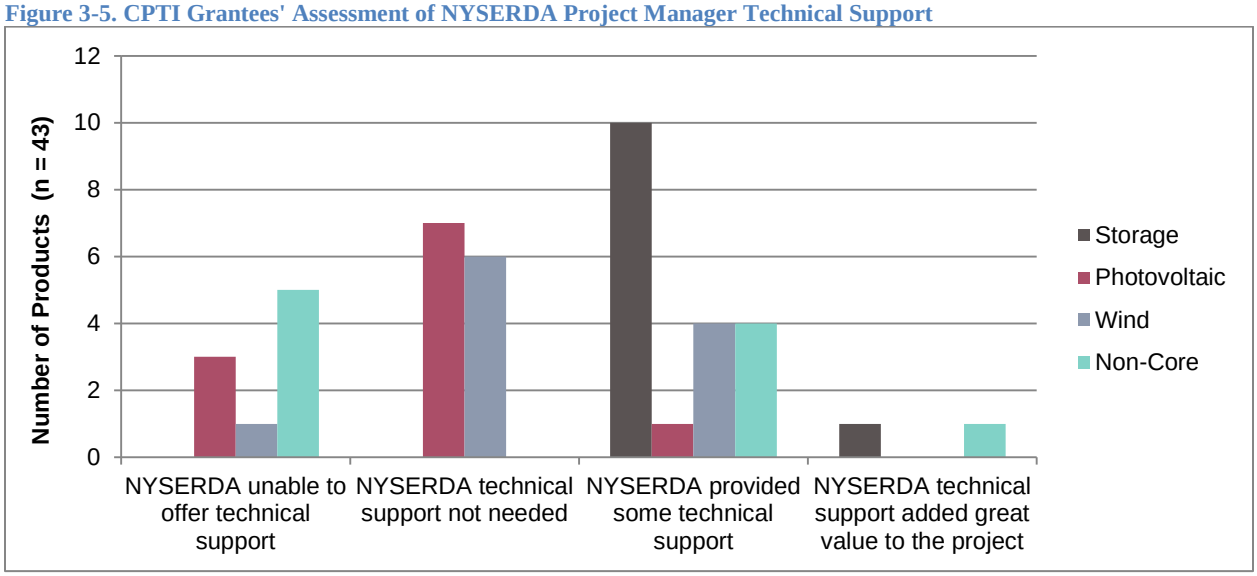
Figure 3-4. CPTI Grantees' Assessment of NYSERDA Project Manager Value



NYSERDA Technical Support. Out of the 43 interviewees who commented on the availability of NYSERDA-provided technical support, 53% indicated that they were not expecting or did not need technical support from NYSERDA. For these interviewees, NYSERDA's role was described as one focused more on business development and product marketing. As shown in Figure 3-5, 26% of interviewees felt that NYSERDA provided support to aid their product research. There were, however, 9 interviewees (21%) who suggested that project managers with greater levels of technical expertise may be better equipped to assist companies when a product confronts an unexpected roadblock. These interviewees also recommended that NYSERDA employ panelists with greater levels of technical expertise during the competitive solicitation process and subsequent project selection.

> *"NYSERDA mostly helped with the business and marketing; the technical side was the responsibility of project engineers."*
> -– Storage product grantee

Figure 3-5. CPTI Grantees' Assessment of NYSERDA Project Manager Technical Support

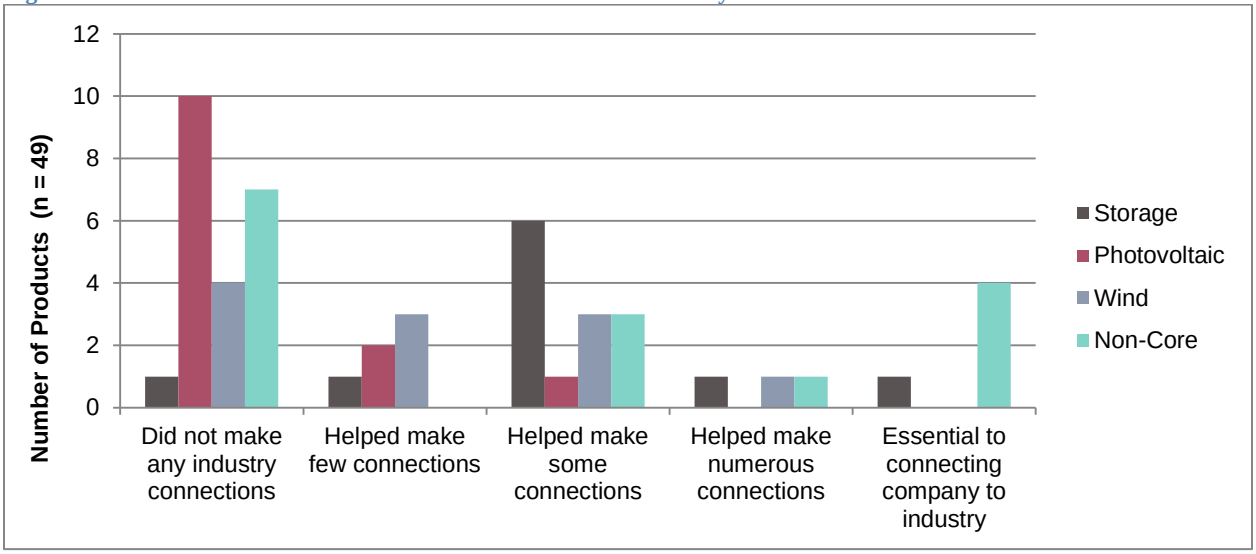


NYSERDA-Driven Industry Connections. NYSERDA CPTI interviewees attributed high value to industry connections, yet 84% suggested that NYSERDA could have done more in this aspect of project support. Interviewees view new industry connections as an important mechanism that can accelerate a product's market uptake or secure additional outside investors. Those products that benefited from NYSERDA-led industry connections highlighted the value of new relationships with testing facilities, local permitting agencies, or sub-contractors who stayed on to become a vital part of their teams. Suggestions on ways to increase industry connections include:

- Establishing and maintaining a database of NYSERDA grantees by sector and geographic area;
- Greater collaboration between NYSERDA and grantees to publicize NYSERDA financial support;
- Stronger market-focused commercialization support; and
- Increased attendance and promotion of local workshops and conferences.

One interviewee also related NYSERDA's ability to foster valuable industry connections to project manager experience, suggesting that project managers with greater field experience or prior experience working in the clean energy industry are more effective in establishing valuable connections on behalf of CPTI grantees within the industry.

Figure 3-6. CPTI Grantees' Assessment of NYSERDA-Driven Industry Connections



3.2 Product Maturation

The interview guide included a series of questions asking grantees to assess the *current* technological and commercial maturity level of their product and the maturity level *prior to* receiving CPTI funding. Using the same technological readiness and commercial readiness scales, the evaluation team conducted a secondary, independent assessment for each interviewee. The evaluation team supplemented this review by also referring to NYSERDA CPTI project descriptions and interview responses regarding CPTI-funded activities, as well as product development activities prior and subsequent to CPTI funding. For completed or cancelled projects, the evaluation team's assessment reflects the TRL/CRL when the project was completed or cancelled, and for active projects, the assessment reflects the current technological and commercial maturity level.[1]

To evaluate product growth, Figure 3-7 displays changes in CPTI product TRL and CRL as matrices. Specifically, Figure 3-7 shows the starting and most current TRL and CRL assessment for each of the 39 Core Products for which interviews were completed. Note that while the TRL and CRL scales run from 1 to 9, the matrices consolidate TRL and CRL scales into low, medium, and high categories. Stoplight gradients (red, yellow, green) are also used to show the concentration of products across the TRL and CRL categories.

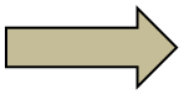
As shown in Figure 3-7, most Core Products received funding from NYSERDA while at the early stages of R&D (upper left or "low-low" cell of the matrix). Product growth is represented by movement down along the TRL axis and to the right on the CRL axis. The "Core Products Current" matrix at the right of Figure 3-7 shows growth toward the medium and high boxes for both TRL and CRL. While almost 80% of the core products investigated were in the low-low box when they began receiving funding from NYSERDA, nearly 54% were rated as medium or high on both TRL and CRL based on the most current

[1] The evaluation team included an explicit TRL/CRL question in the interview guide. While some interviewees were familiar with the scales and were able to respond, the evaluation team member assigned to each product was responsible for the ultimate TRL/CRL assessments. This approach enabled calibration among the team to ensure that products at similar stages were assessed consistently.

available product information. The average TRL growth across all Core Products was 2.8 and average CRL growth was 2.3.

Figure 3-7. CPTI TRL and CRL Matrices, Pre- and Post-Funding

Core Products Pre-funding		CRL		
	n = 39	L	M	H
TRL	L	31	0	0
	M	5	1	0
	H	0	1	1



Legend:
Low (L) – Level 1 to 3
Medium (M) – Level 4 to 6
High (H) – Level 7 to 9

Core Products Current		CRL		
	n = 39	L	M	H
TRL	L	11	0	0
	M	5	7	1
	H	2	6	7

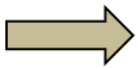
3.2.1 Core Product TRL and CRL Maturation

Disaggregation of the Core Product TRL/CRL growth matrix from Figure 3-7 into separate matrices for each Core Products reveals additional insights across the Core Product categories.

Photovoltaics. The PV TRL/CRL matrix (Figure 3-8) shows some growth along both scales, yet 50% of PV products researched did not move beyond the initial low-low rating. This is largely due to external factors that inhibited the New York (and broader) PV market; as China became a major player in the PV cell design and manufacturing industry, foreign competition increased, which impacted the relevance, unit costs, and market opportunity of many of the projects funded by NYSERDA.

Figure 3-8. Photovoltaics Products TRL/CRL Matrix

	Pre-funding PV	CRL L	CRL M	CRL H
TRL	L	13	0	0
	M	1	0	0
	H	0	1	1

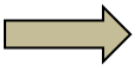


	Current PV	CRL L	CRL M	CRL H
TRL	L	8	0	0
	M	2	2	0
	H	0	2	2

Wind Products. In contrast to PV, nearly all CPTI funded wind products experienced significant levels of both TRL and CRL maturation. Three products were rated as high-high in the current assessment, suggesting that they are commercialized or very near commercialization, providing compelling evidence of that the CPTI-funded wind products achieved CPTI's broader goal to bring new clean energy technologies to market.

Figure 3-9. Wind Products TRL/CRL Matrix

	Pre-funding Wind	CRL L	CRL M	CRL H
TRL	L	10	0	0
	M	1	0	0
	H	0	0	0



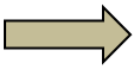
	Current Wind	CRL L	CRL M	CRL H
TRL	L	1	0	0
	M	1	3	1
	H	2	0	3

Storage Products. The storage products (Figure 3-10) fall in between PV and wind. The majority of energy storage products achieved significant levels of TRL and CRL growth, with more products

achieving a higher TRL than CRL. This is also revealing, as the storage industry is more nascent than PV and wind; storage products funded by NYSERDA are generally at an earlier stage, with the majority of CPTI-funded activities achieving a level of demonstrated technical success either in the lab or in the field.

Figure 3-10. Storage Products TRL/CRL Matrix

		CRL		
	Pre-funding Storage	L	M	H
TRL	L	8	0	0
	M	3	1	0
	H	0	0	0



		CRL		
	Current Storage	L	M	H
TRL	L	2	0	0
	M	2	2	0
	H	0	4	2

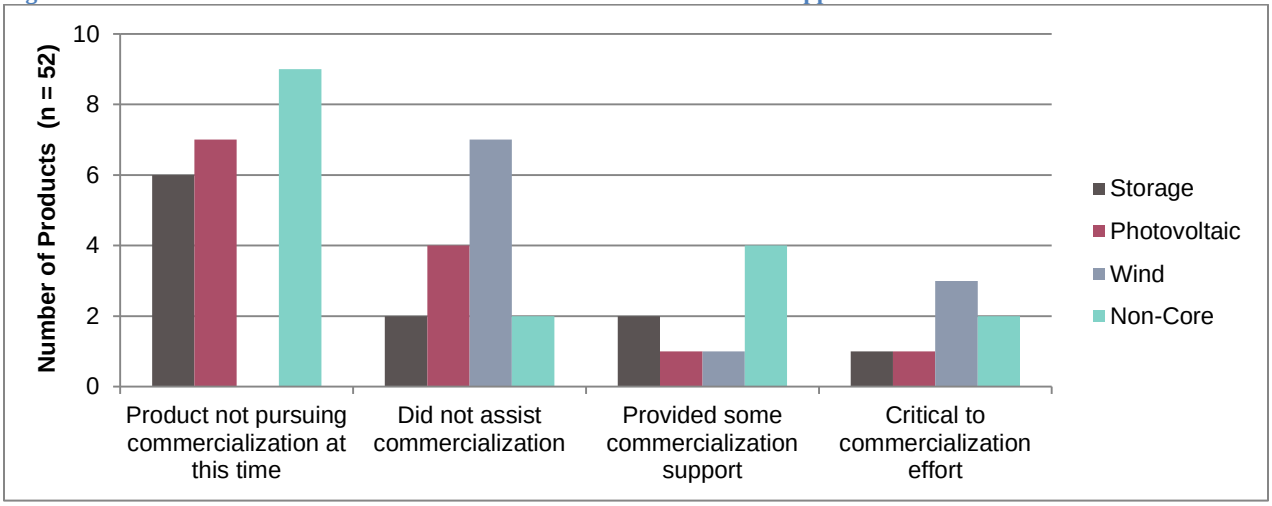
The matrices for the three Core Product align well with the maturity of each respective Core Product industry. Wind is arguably the most mature category, and the matrix shows growth along both TRL and CRL scales. PV is slightly less mature and struggles with cheaper foreign competition, while storage is a more nascent industry and as a result offers greater opportunities for near-term TRL growth but a longer-term trajectory for significant CRL growth.

3.2.2 NYSERDA Commercialization Support

The analysis of TRL and CRL maturation reveals the progress achieved along both technical and commercialization development. To augment this analysis, the evaluation team also explicitly asked CPTI grantees about their efforts and progress toward product commercialization. As shown in Figure 3-11, almost half of all NYSERDA CPTI interviewees reported that they were not pursuing commercialization at the time of the evaluation team's interview. This finding is likely due in part to the wide variety of types of technologies funded by CPTI; the product categories reflect industries at different stages of maturity and near-term commercialization potential.

A large percentage of both PV and energy storage products were not pursuing commercialization at the time of the interview. For PV, this is due, in large part, to external factors such as foreign competition in cell manufacturing. For energy storage, this finding is likely due in part to the timing of CPTI intervention at relatively early R&D stages. In contrast, nearly all wind products were pursuing commercialization at the time of the interview. This split is likely due in part to the fact that most wind technologies have moved beyond basic R&D stage and are more focused on achieving efficiency improvements in existing technology and/or improving the capabilities of energy management software.

Figure 3-11. CPTI Grantees' Assessment of NYSERDA Commercialization Support



3.3 Program Metrics

NYSERDA's Technology and Market Development (T&MD) Operating Plan (Plan) defines a suite of 7 program metrics to evaluate program success. Figure 3-12 summarizes the CPTI program's progress to-date for program years 2012-2016 against the Plan program metrics.[2] While the CPTI program did not achieve its established targets, the program made significant progress towards targeted numbers of contracts completed, and companies supported, with additional project completions expected for products actively under research. While the evaluation did not review all funded products, commercialization progress was noted for several products reviewed.

The remaining Plan program metrics were broader in scope, including metrics focused on developing and commercializing innovative clean energy technologies, improving the technology selection and expanding market adoption within New York State. The evaluation team's assessment reveals some progress for these metrics, as evidenced by the TRL/CRL matrix growth and the in-state retention of CPTI funding. While review of the technology selection criteria was outside the scope of this evaluation, many grantees suggested that improving the technology vetting and selection process is an area for improvement for similar programs in the future.

[2] NYSERDA T&MD Operating Plan. System Benefits Charge. 2013. https://www.nyserda.ny.gov/-/media/Files/About/System-Benefits-Charge/SBC-Five-Year-Operating-Plan.pdf.

Figure 3-12. Assessment of CPTI T&MD Operating Plan Program Metrics

T&MD Operating Plan Program Metric	Assessment	Comment
Contract & Complete 51 Projects		CPTI program funded 41 contracts under T&MD operating plan, 13 projects completed.
Support 64 clean energy companies		CPTI funding for 28 individual companies.
Help 8 companies reach commercial availability		Didn't review all non-core projects but research identified commercialization progress.
Generate $55M in commercial sales		Some sales recorded, though not at the targeted levels. Challenges with data reporting.
Develop and commercialize clean power tech systems that enhance energy management, increase reliability, reduce emissions		General objective, some progress and movement along TRL/CRL scales, some commercialization.
Disseminate objective info about clean power technology to improve decision-making and technology selection		Not assessed - this was determined to be outside of the scope of this evaluation. However, industry experts and grantees suggest this is an opportunity for improvement.
Increase market adoption of Clean Power Technology in NYS		Some progress here. NYSERDA funding is benefiting NY clean technology – many recipients of funding still involved in industry.

3.4 Core Product Research Summary

This section provides additional results from the evaluation team's assessment of the Core Products: PV, wind, and storage. Each section presents a brief summary of the products researched, additional details regarding product growth, and recommendations for future research.

3.4.1 Photovoltaic Products

NYSERDA funded 19 PV projects to assist State innovators in expanding advanced clean power markets in New York. The evaluation team conducted at least one interview with 16 of the PV products and multiple interviews with 3 products, for a total of 25 interviews with PV product-funding recipients. Table 3-1 summarizes the interviews conducted across five primary PV product types. The evaluation team also interviewed three PV industry experts who provided their perspectives on the CPTI product investments and insight into broader market developments.

Table 3-1. Distribution of Evaluated Photovoltaic Products

Photovoltaic Product Category	Number of Products Interviewed
Cell Design	6
Cell Concentrators	4
Cell Metallization	3
Software Cell Design	2
Balance of System Costs	1
Totals	**16**

For analysis, the PV products were divided into four general categories: cell design, cell metallization, concentrators, and software and systems. The following is a summary of the technologies addressed in these projects:

- **Cell design** – The evaluation team interviewed six cell design products researching various facets of PV cell improvements. Many of these products sought to incorporate nano-scale technology to improve cell efficiencies, demonstrate the feasibility of new materials, and/or reduce manufacturing costs.
- **Cell metallization** – The evaluation team interviewed three cell metallization products developing technology to substitute high-cost metals such as silver with lower-cost, non-precious metals such as nickel, copper, and tin. These products generally targeted a reduction in the cost of cell production while retaining efficiency levels.
- **Concentrators** – This category included four products exploring different methods to concentrate solar energy using lenses, films, and other cell coatings. While concentrator PV was a burgeoning subsector of the PV industry near the beginning of the CPTI research period, the declining costs of traditional PV cells, including silicon and other materials, made it difficult for concentrator products to compete.
- **Software and systems** – These products include monitoring software for PV systems for applications such as peak shaving as well as remote monitoring. Also grouped here is a project investigating opportunities to reduce the balance of system (BOS) costs (i.e., everything beyond the cells) within New York State.

PV Technology Program Results

The evaluation team used the TRL and CRL scales to measure the maturity of CPTI-funded PV products. While some products did move along both the TRL and CRL scales, the average TRL growth for the PV products evaluated was 1.4 and the average CRL growth was 1.1. The growth of each product evaluated is shown by category in Figure 3-13 and Figure 3-14 for TRL and CRL, respectively. While this product-level view shows some growth in both technological and commercial development, 9 of the 16 PV products experienced little to no growth, as illustrated in the diagonal bars within each figure. Many of the PV products, including those in the metallization, concentrator, and cell design categories, were designed to reduce the cost of PV by substituting inexpensive materials and/or reducing the amount of silicon in cells. As China became a major player in PV cell development within the last 10 years, PV costs decreased greatly, rendering many of the PV CPTI-funded products less relevant.

Figure 3-13. PV TRL Maturity by Product[3]

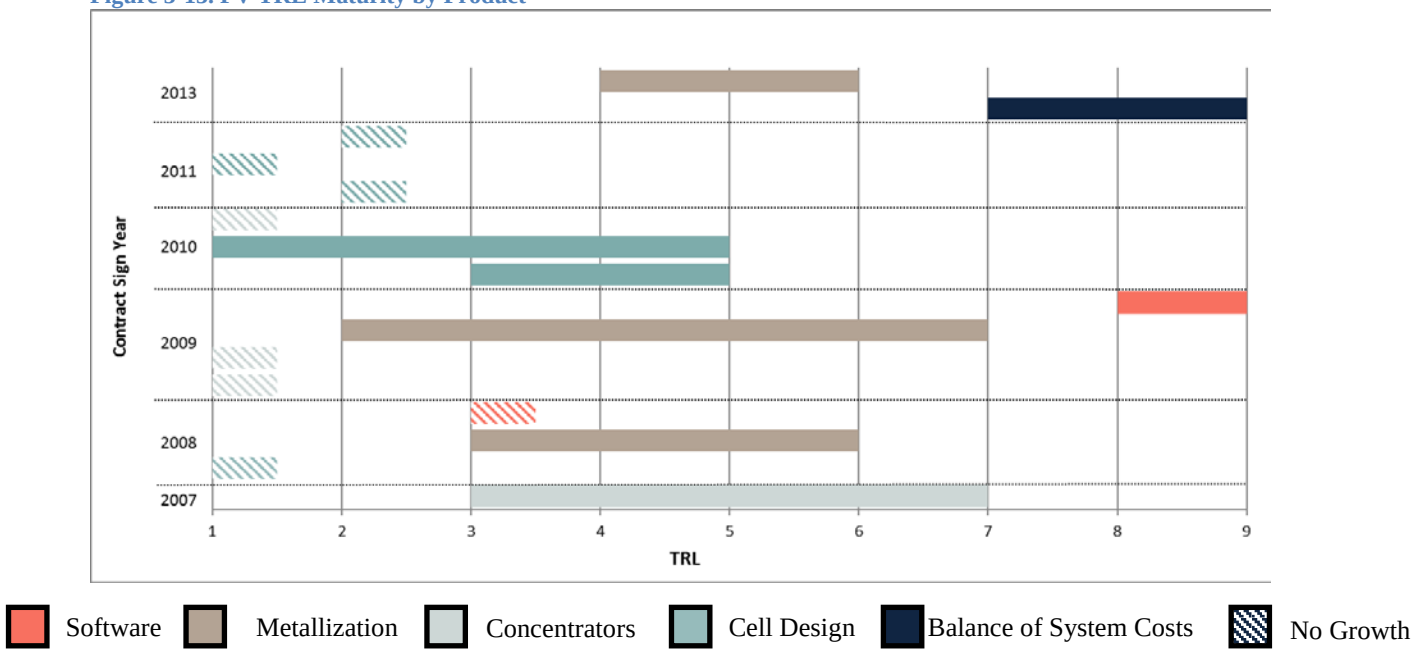
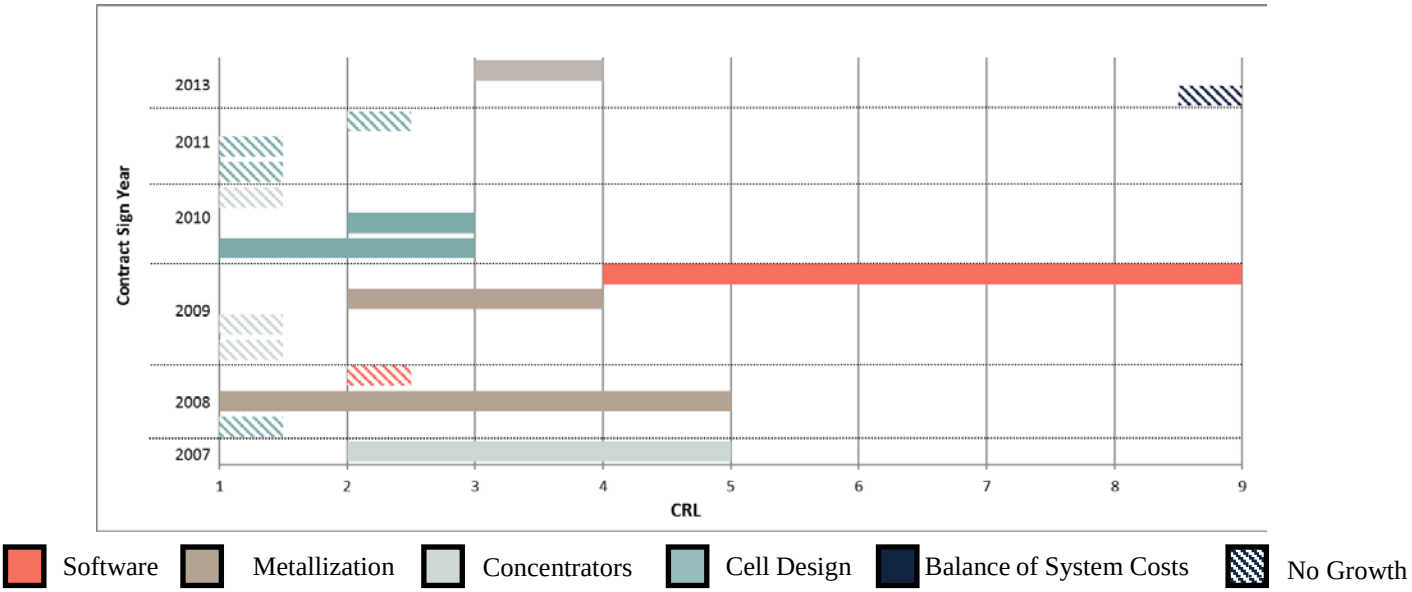


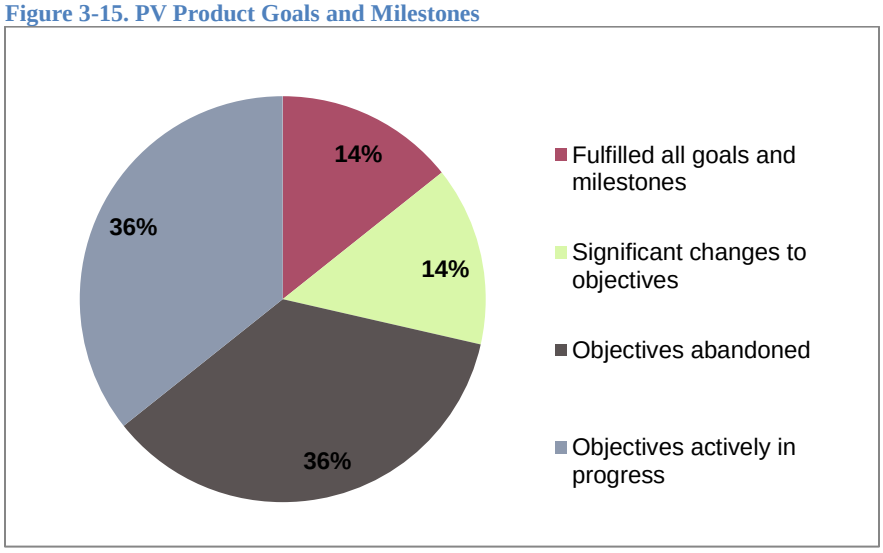
Figure 3-14. PV CRL Maturity by Product



The increase in foreign competition in the PV market hindered the ability of many products to achieve the objectives established during the contracting process with NYSERDA, as illustrated in Figure 3-15 which presents PV product progress against contract goals and milestones.

[3] In Figure 3-13 and Figure 3-14, each bar represents one product, color-coded by category. The endpoints of each bar represent the product's starting TRL/CRL and its ending TRL/CRL.

Figure 3-15. PV Product Goals and Milestones



Barriers and Keys to Product Successes

While many of the CPTI-funded PV technologies are still in the R&D pipeline and not yet commercially viable, results of the interviews suggest that funding from NYSERDA has allowed some projects to reach successful commercialization. Approximately 56% of the evaluated PV products indicated that funding was essential or highly valuable to their research. While 7 of 16 PV products achieved notable success as measured by TRL and CRL maturation growth, the majority of CPTI-funded PV products encountered challenges to maturation. Many CPTI-funded PV products experienced little to no TRL and CRL movement largely due to external factors such as foreign competition and market changes. Manufacturing of PV cells is trending abroad, limiting future applications of cell manufacturing in the United States (including in New York State). Additionally, virtually all progress in PV R&D for several decades has been from small, incremental improvements in efficiency, cost, and materials. Other barriers include cost-related issues, scalability, safety concerns, and the challenges of the market/customers to quickly adapt or recognize product value.

Recommendations for Future Research

Future research, development, and commercialization support in the PV industry should be made in consideration of specific goals for the State. To that end, those goals need to be focused and specific rather than vague (e.g., generate jobs, build a renewable industry in the state, etc.) so that the success of PV-specific support efforts can realistically be measured.

The following are recommendations based on the interviews with PV industry experts:

- The near-term value-added to the PV industry in New York State is through PV installations, rather than through manufacturing. NYSERDA may be most effective by supporting increased installation of PV through incentives, soft cost reductions, and similar mechanisms.
- Virtually all the progress made in PV was made through small, incremental improvements, not radical, game-changing breakthroughs. NYSERDA should continue to support viable New York companies that can make these important incremental improvements**, provided**:
    - It can be determined that a successful outcome of a particular project will in fact yield an important (albeit) small benefit given the technological and commercial status of the

industry at the time. This requires those who vet the proposed projects to have *both* current technological and commercial knowledge of the industry.

  - Incremental improvements, although valuable, are usually associated with components of PV cells and modules. Given the state of PV manufacturing in New York State and world-wide market forces, component improvements are likely to end up being implemented by companies outside of the U.S. (and by extension, outside of New York State), with little or no local commercial benefit. If these technologies are supported, NYSERDA should carefully consider how the successful development would benefit New York State.

- High reward, high risk breakthroughs may still be worth pursuing, especially at the university level. However, and even more important than with incremental improvements, NYSERDA should have a solid understanding of the actual commercial and technological benefits should the development be successful.
- Incubators and business plan competitions are excellent ways NYSERDA can nurture nascent technologies, bring better technologies to the forefront, and expose start-ups to investors.
- There should be limits on funding timelines or the number of rounds of research funding to encourage efforts to commercialize or demonstrate and to prevent keeping "zombie" technologies alive. NYSERDA should avoid funding companies that are research grant "mills" that show little motivation toward commercialization.

3.4.2 Wind Products

NYSERDA funded 16 wind technology projects through the CPTI program. The evaluation team conducted at least one interview with 11 wind products, and multiple interviews with 5 products for a total of 16 CPTI-funded wind product interviews. In addition, the evaluation team conducted interviews with five industry experts who provided their perspectives on the CPTI product investments and their insight into broader market developments.

CPTI-funded wind products were generally divided into three categories: advanced wind turbine designs, wind turbine modeling and software, and secondary technologies. Table 3-2 shows the distribution of the 11 evaluated wind technology products among these three categories.

Table 3-2. Distribution of Evaluated Wind Products

Wind Product Category	Number of Products Interviewed
Advanced Wind Turbine Design	5
Wind Turbine Modeling and Software	5
Secondary Technologies	1
Totals	**11**

The following is a summary of the technologies addressed in these projects:

- **Advanced wind turbine designs** – Industry experts report that turbine manufacturers invest large amounts of funding into blade design themselves and are unlikely to purchase third-party-developed designs. The evaluation team interviewed five products researching various features of advanced wind turbine designs, including novel wind turbine designs such as vertical turbines and turbines operable at low wind speeds, small-scale designs for distributed generation, and improved turbine blade controls that reduce stress on blades, allowing them to be longer. While research is ongoing in

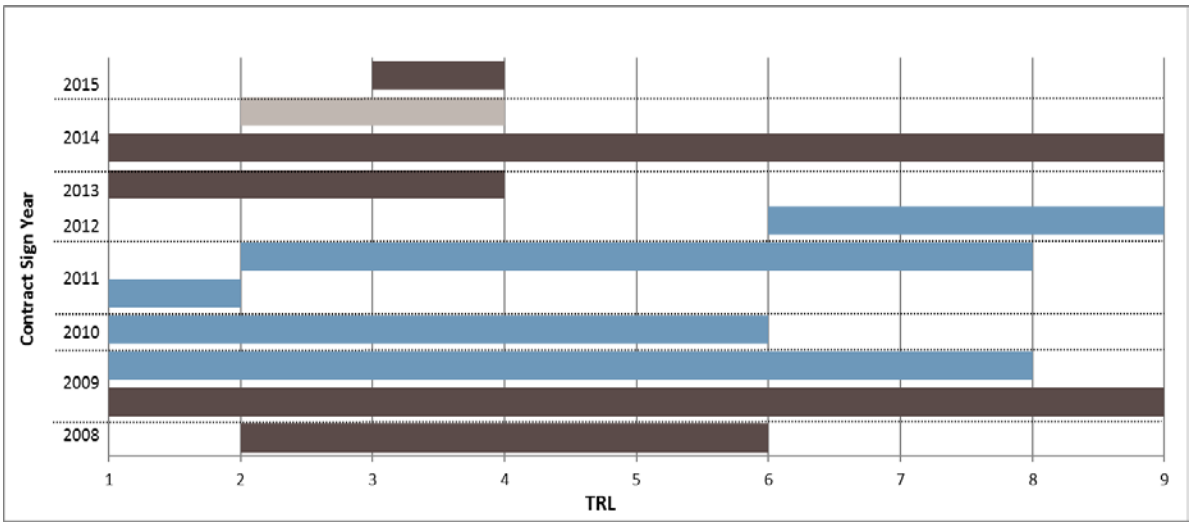
advanced wind turbine designs, the traditional three-blade turbine is the most successful wind turbine design to-date and is unlikely to be replaced in the near term by novel approaches.

- **Wind turbine modeling and software** – This category encompassed five products targeted at developing wind turbine structural and predictive health monitoring systems. Three of the predictive health monitoring systems were commercially successful and are now available in the market, suggesting that the products were well-timed with wider industry developments and customer demand. The most successful products also included the products that reported the most substantial amounts of outside funding and industry connections. Looking forward, industry experts indicated that further research in this area as a retrofit technology may not be as productive because large wind turbine manufacturers are increasingly integrating monitoring systems into their turbines during fabrication.
- **Secondary technologies** – The evaluation team assessed one product aimed at developing a novel generator design utilizing high efficiency heat rejection to reduce size and weight. Industry expert interviews indicated that power train components are an area of the industry that has room for improvement.

Wind Technology Program Results

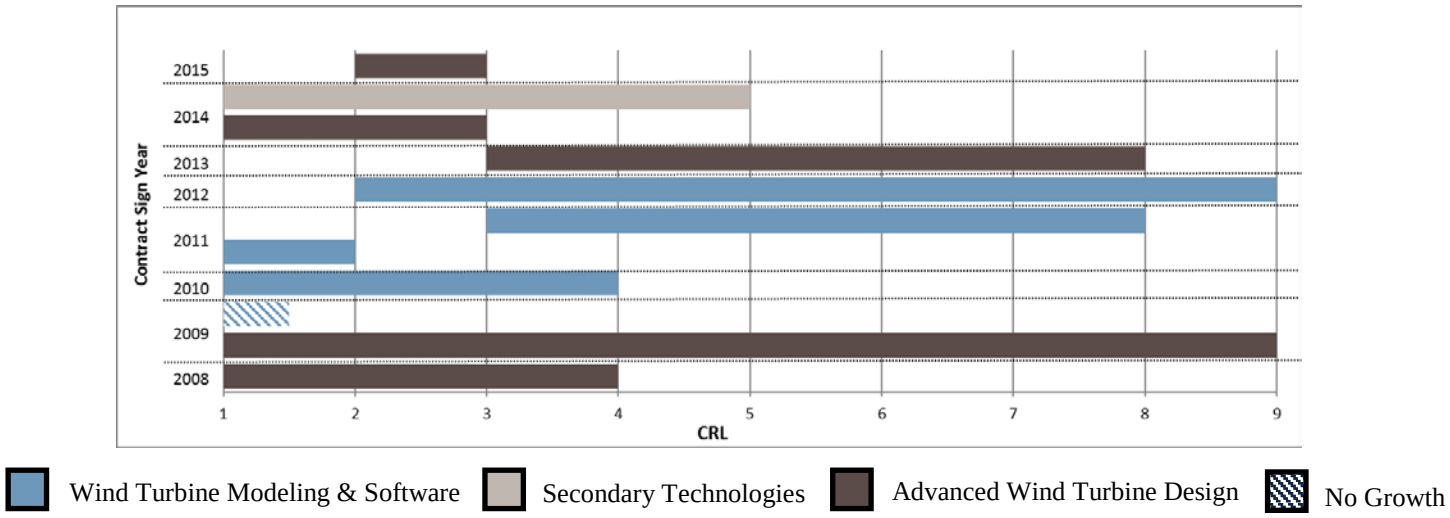
As shown in Figure 3-16 and Figure 3-17, CPTI-funded wind products showed strong growth along both the TRL and CRL scales.

Figure 3-16. Wind TRL Maturity by Product[4]



[4] In Figure 3-16 and Figure 3-17, each bar represents one product, color-coded by category. The endpoints of each bar represent the product's starting TRL/CRL and its ending TRL/CRL.

Figure 3-17. Wind CRL Maturity by Product

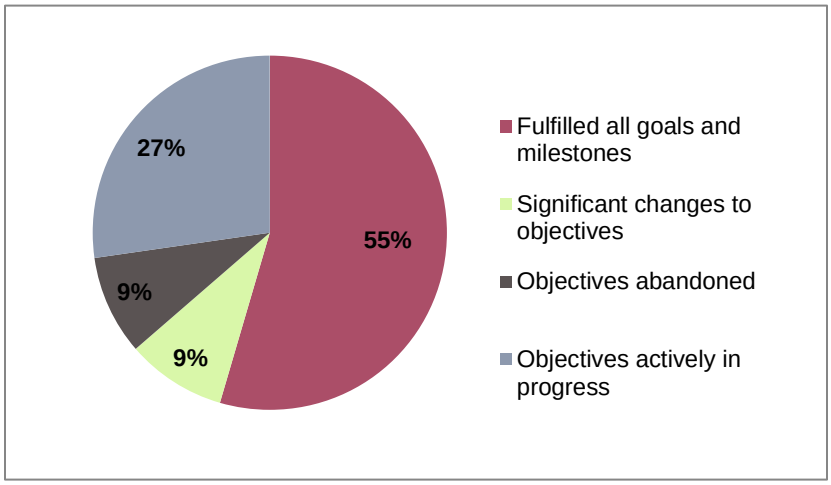


The average wind product TRL growth was 4.4, and the average CRL growth was 3.5. Most products saw significant growth on both scales as a result of participation in the CPTI program. Products that struggled to commercialize generally did so because they did not fit an industry need, or addressed a need that manufacturers are developing themselves. Successful products were characterized by strong industry connections, investor support, and a specific industry need.

Barriers and Keys to Product Successes

Major factors that contributed to the success of wind turbine products include a need in the industry for predictive health software and continued opportunity for turbine designs that improve longevity and reduce overall energy generation costs. In support of these findings, most CPTI-funded wind products accomplished the majority of their research goals. Products that struggled faced challenges primarily with commercialization and marketing to the commercial wind turbine market. Expert interviews indicated that commercial wind turbine manufacturers often perform their own in-house research and development on core turbine components, and they are unlikely to purchase or utilize third-party-developed designs unless they offer unique advantages. Figure 3-18 shows the progress of wind products against their initial goals and milestones.

Figure 3-18. Wind Product Goals and Milestones



Recommendations for Future Research

All of the wind industry experts interviewed agreed that the most important research goal for the industry going forward should be to reduce the cost of wind power generation. This can be achieved through a variety of methods, including research to reduce capital costs, reduce operation and maintenance costs, improve turbine efficiencies, and extend equipment life. Improvements to the design of power train components, particularly in relation to weight and efficiency, are the primary technology-related opportunities for wind turbines. Power train components include the following:

- Rotor – turns wind into motion;
- Gearbox – converts low rpms of rotor to high rpms for generator;
- Brake – stops or controls the rotor motion; and
- Generator – converts shaft rotation into electrical energy.

In the evaluation team's literature review[5,6,7], two technologies emerged that seemed to hold particular promise for improving existing wind turbines: improved rotor designs that either passively or actively shed stress from turbulent or high winds, and direct drive turbines, which eliminate the need for a gearbox. These findings were supported through the team's interviews with industry experts.

Multiple experts reported that energy storage is critical to the future of wind power generation, and there is a need to reduce the soft costs associated with the development and siting of wind turbines. Experts reported that certain interconnection requirements from utilities and transmission owners are very cost-intensive, and there is a need for development of lower-cost solutions. By furthering technology solutions

[5] Thresher, R., Robinson, M., and Veers, P. Wind Energy Technology: Current Status and R&D Future. National Renewable Energy Laboratory. August 2008. http://www.nrel.gov/docs/fy08osti/43374.pdf.

[6] U.S. Department of Energy. Wind Vision: A New Era for Wind Power in the United States. March 2015. https://www.energy.gov/sites/prod/files/wind_vision_highlights.pdf.

[7] U.S. Department of Energy. 2014 Wind Technologies Market Report. August 2015. https://energy.gov/sites/prod/files/2015/08/f25/2014-Wind-Technologies-Market-Report-8.7.pdf.

that reduce wind-power soft costs and improve turbine life, availability, and efficiency, NYSERDA can have a significant effect on the wind industry as a whole.

3.4.3 Storage Products

The evaluation team conducted in-depth interviews with 12 of the 16 energy storage products funded by the CPTI program, equal to a response rate of 75%. In terms of specific technology types, batteries were the most common technology represented by respondents, with seven of twelve respondents (or 58% of all respondents), followed by ultracapacitors with three respondents, and flywheels with two respondents.[8] In addition, the evaluation team also conducted interviews with five energy storage industry experts who provided their perspectives on the products funded and insight into broader market developments.

Table 3-3 shows the distribution of interview respondents by technology type and application. As shown, grid scale and self-contained applications were the most common energy storage applications funded by the CPTI program. According to energy storage experts, the type and breadth of technologies funded by the CPTI program is diverse and generally falls in line with wider trends in the energy storage market.

Table 3-3. Distribution of Evaluated Storage Products

	Application Type			
	Grid-Scale	Self-Contained	Transportation	Total
Battery	3	3	1	7
Flywheel	2	0	0	2
Ultracapacitor	0	2	1	3
Total	5	5	2	12

Storage Program Results

All of the 12 energy storage products evaluated achieved some level of technical and/or commercial growth. In almost every case, the product has been proven in the lab or field to be technically successful. The average TRL growth for CPTI-funded energy storage products was 3.2, and the average CRL growth was 2.7. Notably, CPTI-funded contracts for 6 of the 12 energy storage products evaluated are still ongoing, indicating the potential for further TRL and CRL growth.

As shown in Figure 3-19 and Figure 3-20, battery products achieved the highest overall growth compared to other storage technologies, with an average TRL growth of 3.9 and an average CRL growth of 3.3. Of the seven battery products evaluated, four products achieved TRL increases of five or more points along the scale. According to subsequent discussions with energy storage market experts, batteries may have an

[8] Six of the 12 energy storage projects evaluated were also NY-BEST members who received funding through the Clean Air Interstate Act (CAIR). CAIR provided $25 million of its proceeds towards NY-BEST R&D activities. More information on NY-BEST can be found in the project report. https://www.nyserda.ny.gov/About/Publications/Program-Planning-Status-and-Evaluation-Reports/Evaluation-Contractor-Reports/2017-Reports.

easier time achieving greater technological and commercial growth than other technology types (such as flywheels) because of their adaptability and applicability to both large-scale and small-scale applications.

Figure 3-19. Storage TRL Maturity by Product[9]

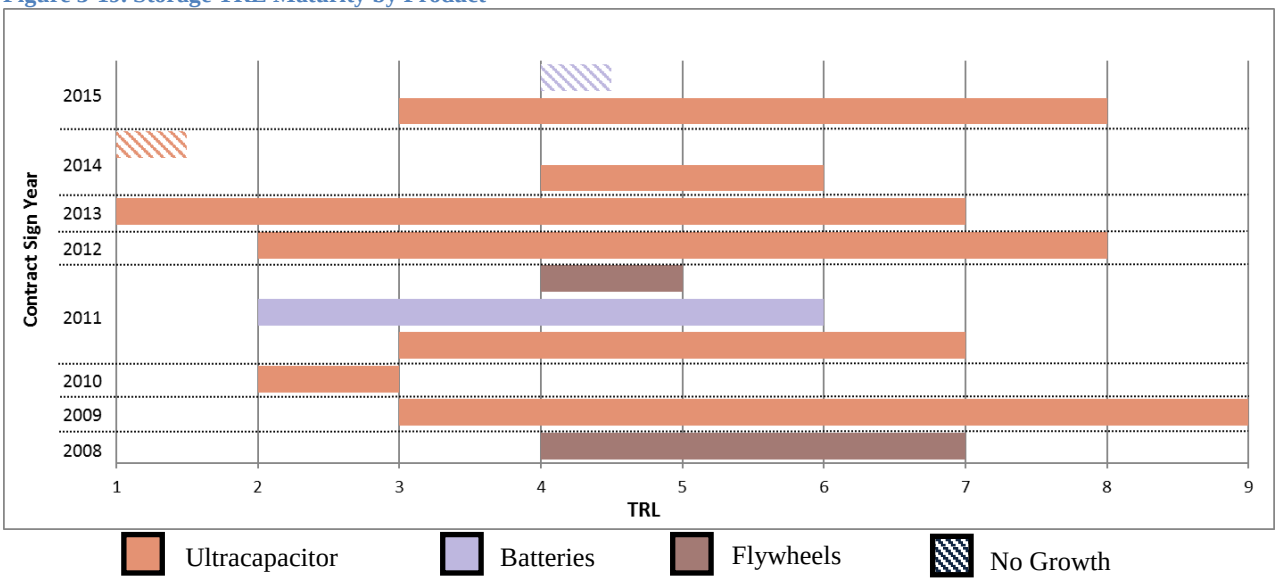
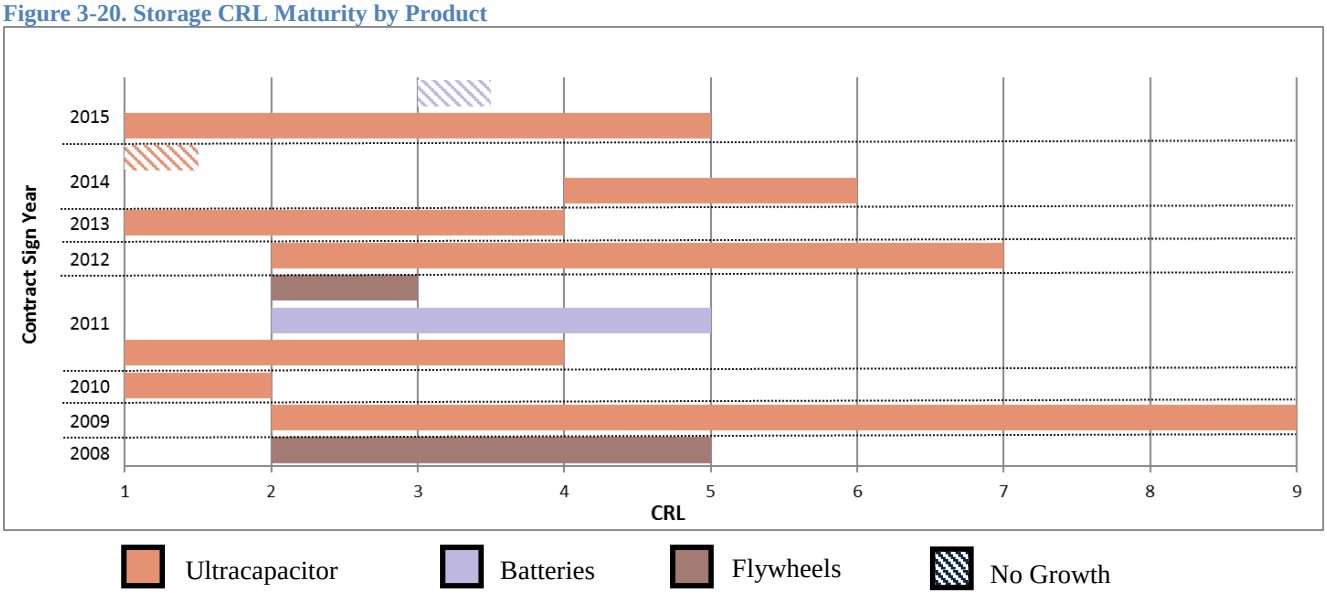


Figure 3-20. Storage CRL Maturity by Product



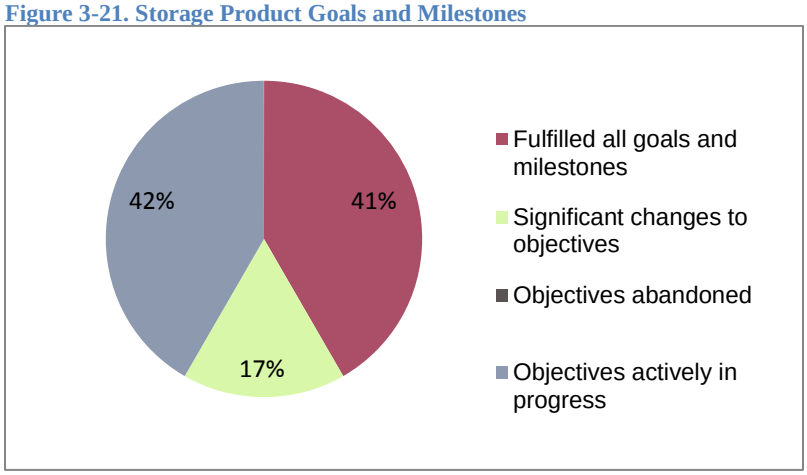
Barriers and Keys to Product Successes

The majority of the evaluated storage companies (7 of 12) funded by CPTI are still operational, with five companies in various states of product testing and two companies in advanced stages of commercialization. Another two products are inactive but have completed their NYSERDA-funded

[9] In Figure 3-19 and Figure 3-20, each bar represents one product, color-coded by category. The endpoints of each bar represent the product's starting TRL/CRL and its ending TRL/CRL.

research, and three are inactive with the project on hold. As stated earlier, six CPTI contracts are still ongoing. Costs have been a limiting factor for the products that are no longer in development. The two inactive products associated with completed contracts have not pursued commercialization or further development due to high costs and competition from other technologies. For the projects that are on hold, uncertainty exists about whether the grantees will complete the work specified by the CPTI contract.[10] For example, one storage technology has successfully demonstrated its technical readiness, but the company determined the technology was financially infeasible at the present time. Figure 3-21 shows the progress of storage products against their initial goals and milestones.

Figure 3-21. Storage Product Goals and Milestones



CPTI funding of energy storage products included new and previously untested technologies where success is not assured. As such, the interview guide included open-ended questions asking interviewees to identify the greatest challenges to achieving greater technological and/or commercial success. As shown in Table 3-4, a market slow to adapt to new energy storage technologies was the most common challenge reported by interviewees. For example, several companies indicated difficulty working with and introducing their products to large institutional customers such as utilities. Despite recent growth, the energy storage industry remains a relatively nascent market.

Other key challenges identified by the interviewees centered on cost, including high manufacturing costs, competition from lower cost lithium-ion batteries, and competition from foreign products. One interviewee also cited challenges with energy storage safety (e.g., fire hazard).

[10] Future NYSERDA funding programs intend to track such projects that are on hold for an extended period of time, and evaluate these projects for early closing.

Table 3-4. Summary of Storage Product Commercialization Barriers

Commercialization Barrier	Number of Products*
Cost	5
Market slow to adapt	4
Competition	3
Safety	1
* Interviewees allowed multiple responses	

Recommendations for Future Research

Industry experts were asked a series of open-ended questions about the most interesting and/or important areas of research to achieve wider adoption rates of energy storage technologies. The experts consistently agreed that the most effective way to support the industry is through policy mandates and market incentives. Existing policy mandates and market incentives have been key drivers of the industry's growth, in certain service markets, to date. At the state level, California's 2013 energy storage mandate requires California's three largest utilities to add 1.3 gigawatts of energy storage to the grid by 2020. At the federal level, Federal Energy Regulatory Commission (FERC) order 784, enacted in 2013, helps open the ancillary services market to energy storage by allowing faster forms of energy storage resources, such as batteries and flywheels, to compete with slower gas- or coal-fired plants. FERC order 784 expanded on FERC order 755, which increased the compensation for "fast" and accurate responding sources such as batteries and flywheels that bid into frequency regulation service markets. Additional mandates and market incentives that build on these existing incentives can serve to further accelerate industry growth; experts suggested expanded energy storage mandates, tax credits, and rate structure changes that allow locational and time-based pricing.

A second common and related theme identified by industry experts is the need for dramatic reductions in manufacturing costs. While current expectations are that energy storage costs will fall over the next five years, financial support for projects targeted specifically at reducing energy storage manufacturing costs can help to bridge the gap between development and deployment. This theme was echoed by some of the CPTI grantees who described the concept of "first customer" funding, or funding designed to reduce the higher unit costs that first customers often face for new types of technologies. First customer funding programs can help companies achieve larger volume orders. These in turn lower manufacturing costs while concurrently providing the means for the development of commercial-scale performance data that will help technologies and technology developers gain market credibility. Another expert described this concept as a form of customer acquisition support, providing customers with financial incentives that will help manufacturers overcome the commercialization "hump."

A final common theme among industry experts is the suggestion to prioritize a system-based funding strategy. For example, rather than supporting a specific type of battery chemistry, consider funding energy storage as part of an energy system. One expert pointed to a recent microgrid project in Denver, Colorado, as an example of a systems-based funding strategy. The project consists of multiple components, including positioned solar, storage modules, and a small wind turbine on top of a transportation hub. Through this configuration, the project creates five separate revenue streams across three project owners. This project is an example of a system-based approach that serves as a testing

ground for not only how energy storage interacts with other energy generation technologies, but also how different streams of value can be captured by different project owners. This expert further clarified his suggestion as a funding strategy that targets projects that test the future of energy systems; in other words, these are complex, algorithm-driven energy systems generating multiple value streams that benefit multiple owners.

The following are other suggestions from industry experts for future areas of research:

- Energy management systems and advanced modeling software designed to optimize energy storage and how energy storage interacts with the grid and optimizes grid needs;
- Increasing energy density to meet grid-scale energy storage demand;
- Recycling/end-of-life applications for batteries;
- Battery safety, especially to reduce fire risk;
- Energy storage projects that target grid resiliency;
- More incubator spaces to speed manufacturing scale-up and commercialization of energy storage technologies; and
- Greater collaboration with other states that have the same or similar goals and/or challenges.

4 Conclusions and Recommendations

Overall, funding through the CPTI program has been very successful. The majority of grantees indicated that NYSERDA funding has been essential to their R&D activities. Additionally, grantees in the PV, wind, and storage Core Product sectors achieved moderate levels of both technological and commercial growth, with an average TRL and CRL growth of 2.8 and 2.3, respectively.

While the program has largely been successful, the evaluation team offers the recommendations below for improving future funding offerings under the RRO program.

4.1 Recommendation 1: Provide strategic funding designed to bridge the gap between R&D and commercialization

In order to increase market acceptance of clean energy generation and create a self-sustaining clean energy industry in New York, funding should be provided for a balanced mix of early- and late-stage products. While CPTI-funded products achieved moderate levels of technological and commercial growth, significant challenges remain to achieve full-scale commercialization. Emerging clean energy technologies generally face financing gaps at two stages of development: during early stage R&D and during later pre-commercialization stages. This evaluation found appreciation among grantees for NYSERDA's support during early-stage R&D and proof-of-concept efforts, but interviewees and experts agreed that more support is needed to help clean energy innovators bridge the gap between development and deployment. Notably, later-stage work typically requires larger capital investments in order to test and refine product design and build-out manufacturing capabilities needed for full-scale commercialization; the risk and return profile of these later stages of product development can make it challenging to attract substantial outside investment.

Bridge funding, provided specifically for the purpose of advancing commercialization, addresses the later-stage financing gap and the barrier that clean energy innovators often encounter as they attempt to move from technology development through the manufacturing and production stages to full commercialization. One possible strategy is to target bridge funding at technologies with proven technical success, for example technologies at TRL and CRL 5 to 7 that have completed successful small-scale demonstrations and, consequently, are well-positioned for subsequent stages focused on scaling for in-field demonstrations and manufacturing. Technologies at this phase often still require significant support in order to bring research concepts to the marketplace. Greater strategic emphasis on product development, product demonstration and field testing is also consistent with the direction articulated recently in NYSERDA's March 2017 Clean Energy Funding Investment Plan.

The appropriate form and structure of bridge funding depends on current and projected market conditions and the relative maturity of the industry sector; bridge funding may be more effective for nascent industries such as energy storage rather than wind and solar, which are further along the development curve. Some interviewees expressed caution for companies to take advantage of grant programs absent a formal strategy for bridge funding. Development of well-defined selection criteria complemented by performance metrics can reduce the risk of creating companies overly reliant on grant funding, and provide program administrators with a means to refine program design to better achieve programmatic goals and impact.

4.2 Recommendation 2: Prioritize "First Customer" funding for successful technologies

The evaluation team recommends NYSERDA consider opportunities for prioritizing "first customer" funding for successful technologies. A number of interviewees identified prohibitively high manufacturing costs as a significant barrier to commercialization. Because unit costs are almost always high in the beginning of the manufacturing process, it is difficult to attract customers. To incentivize early adopters to support commercially untested technologies, the evaluation team recommends considering strategies such as grants that reduce the manufacturing costs of products to first customers, or adjusting recoupment terms to include a "first customer" provision in which NYSERDA (or participating New York State agencies) agrees to purchase or implement technologies from successfully demonstrated projects. This type of support can help accelerate NYSERDA grantees and technologies into the commercial marketplace by mitigating the uncertainty and technology risk that first customers face, and by providing a means for clean energy start-ups to recoup initial costs to a point where additional manufacturing is financially feasible.

4.3 Recommendation 3: Enhance networking

When asked for suggestions about other types of support or assistance, the most common suggestion from interviewees was greater networking. This evaluation found a degree of inconsistency with respect to the number of introductions and connections provided by NYSERDA to grantees. Industry connections are vital to product success, and NYSERDA is well-suited to facilitate strategic partnerships between clean energy start-ups and potential commercial partners (e.g., subcontractors, investors, incubators, and VC) and/or customers. In addition to creating connections to potential partners and customers, NYSERDA can also foster connections across sectors – for example, across the solar, wind, and storage sectors of New York's clean energy industry. Greater internal collaboration between the RRO program and NYSERDA's Technology to Market team can further contribute to fostering connections within and across sectors. Networking events and workshops that bring together grantees and other clean energy actors and stakeholders can be powerful tools for advancing clean energy innovation in the State. Ultimately, additional networking support may lead to both monetary and non-monetary rewards for the emerging technologies supported by NYSERDA grant programs.

4.4 Recommendation 4: Hold back 3%–5% of funding for post-grant metrics reporting

Program staff should consider integrating financial incentives to increase post-grant reporting of recipient accomplishments and metrics. This evaluation found that NYSERDA's metrics database, which is supposed to store performance measurement data from funding recipients, has an extensive problem of missing data due to under-reporting. This made it difficult to accurately quantify the impact of NYSERDA's programs using metrics such as jobs and sales. For the CPTI program, only half of the required data was complete in NYSERDA's metrics database. The evaluation team recommends NYSERDA consider establishing a grant provision under which 3%–5% of grant funding is held back contingent on the submission of complete post-grant reporting. Grant funding could be incrementally released over a period of five years, with one to two percent of the funding being released for each year of successful reporting. Such a "retainage" provision already exists for some NYSERDA contracts, and as a

result, NYSERDA likely has the accounting systems in place to implement a holdback provision. Post-grant reporting serves a key source of data that enables robust evaluation of program impact, and tracking the progress and contribution of funding programs to strategic goals such as job creation, economic development, and emissions reductions.

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Appendix A: Acronyms and Abbreviations

CRL	Commercialization readiness level
CAIR	Clean Air Interstate Rule
CEP	Comprehensive Evaluation Plan
CPTI	Clean Power Technology Innovation
DARPA	Defense Advanced Research Projects Agency
DOE	U.S. Department of Energy
EPRI	Electric Power Research Institute
FERC	Federal Energy Regulatory Commission
GHG	Greenhouse Gas
NSF	National Science Foundation
NY-BEST	New York State Battery and Energy Storage Technology
NYPA	New York Power Authority
NYSERDA	New York State Energy Research and Development Authority
PV	Photovoltaic
R&D	Research and Development
RRO	Renewable Resource Optimization
SBIR	Small Business Innovation Research
T&MD	Technology and Market Development
TRL	Technology Readiness Level

Appendix B: Core Product Interview Guide

Interview Guide – CPTI Phase 2 Core Technologies Projects

Introduction:
NYSERDA has contracted with Energy & Resource Solutions, Inc. (ERS) and Industrial Economics, Inc. (IEc) to document success stories and lessons learned from projects funded by NYSERDA's Clean Power Technology Innovation (CPTI, also previously called Power Systems, a component of the Advanced Clean Power) program. To achieve this, we would like to collect background information about your company and discuss the development of your project supported by the CPTI program, including product benefits, achievements, and NYSERDA's role in the process.
We have collected some initial information on __[*insert project name/description]*__ from NYSERDA metrics data and publicly available information, and would like to confirm this information and cover some additional topics. This conversation should take no longer than one hour.

Company & Project Background Information

1. Can you please provide us with a brief company history from your perspective and your role at the company?
    a. Have there been any changes in ownership or management? Please describe.
    b. Is the technology that you received NYSERDA CPTI funding for still being actively pursued? Why or why not?
        i. What market need does the technology fill?
    c. Has your company been sold or acquired subsequent to the NYSERDA CPTI funding? By or to whom?
    d. Have any of the key individuals gone on to other companies in the industry? If yes, please describe.

NYSERDA CPTI **Funding Activities**

2. We've reviewed the NYSERDA program data but it would be helpful to hear from you how the NYSERDA program grant and the grant process fit into the company history and strategy.
3. Why did you decide to apply for NYSERDA CPTI funding for the development of this product/technology?
    a. How did you find out about the NYSERDA CPTI program?
    b. We'd like to confirm the grants provided by the NYSERDA CPTI program.
        i. [*Confirm contract-specific funding and time period]*
4. Consider a technology or product development timeline from 1 to 9 where "1" represents an initial idea or concept and "9" represents a fully developed product available for commercial sale/application. Let's look at this separately from both a technology readiness and commercialization readiness perspective. Please refer to the tables provided to you outlining the different levels of the scale.
    a. From a technology readiness perspective, at what number in this scale were you when you applied for NYSERDA CPTI funding?
        i. Commercialization?
    b. From a technology readiness perspective, at what number were you when you received NYSERDA CPTI funding?
        i. Commercialization?

    c. Where along this scale would you estimate you are now for technology?
        i. Commercialization?
    d. Without NYSERDA CPTI funding, do you the think technology development would be further along, behind, or about the same? Please describe.
        i. Commercialized sooner, later or not at all? Please describe
5. If you had not received funding from NYSERDA, what would have been the impact on your research and development activities for this product?
6. Did you receive any other grants from NYSERDA in addition to CPTI during this period? Please describe.
7. Outside of NYSERDA, did you receive any other grants for this technology/product during this period? Please describe.
8. Approximately what percentage of total available funds did the NYSERDA CPTI grant represent?
9. Can you recall what the NYSERDA CPTI grant specifically funded? For example, general operating costs, adding new employees, equipment/capital purchases, etc.
10. What is your estimate of the percentage of these funds that went to NY-based direct employment vs. employment or the purchase of goods/services outside of NY?
11. Can you please reflect on any additional assistance NYSERDA provided beyond just the CPTI grant?
    a. Did NYSERDA directly or indirectly through the application influence your strategy or business plan? [If yes probe how/why]
    b. Did NYSERDA offer advice or guidance during the process? [If yes probe for details]
    c. Have you participated in any 3rd party consulting/advice arranged through NYSERDA, such as the Entrepreneur-in-Residence program? [If yes robe for details]
    d. Did NYSERDA connect your firm with other firms or individuals that were helpful for advancing product development/commercialization? [If yes probe for specifics]
    e. Did NYSERDA's funding encourage or help you attract other investment in your product/company? [If yes probe for how/from whom]
    f. Were there any other services provided by NYSERDA that we have not covered?
12. Please rank the value of the following NYSERDA services on a scale between 1 and 5, where 1 represents no value to the company and 5 represents indispensable value to the continued operation of the company.
    a. NYSERDA CPTI Funding
    b. Other NYSERDA Funding
    c. Changes to application and/or research strategy
    d. NYSERDA project manager assistance
    e. Third-party consulting, such as the Entrepreneur-in-Residence program
    f. Establishing useful connections/introductions
    g. Other (probe for specifics)
13. Did NYSERDA's administrative requirements, such as meeting deadlines and specific deliverables, in any way adversely affect: (1) your ability to advance the development of your product/technology or (2) your progress in commercializing your product/technology? If yes, explain.
14. Did NYSERDA's contracting process in any way adversely affect (1) your ability to advance the development of your product/technology or (2) your progress in commercializing your product/technology? If yes, explain.
15. What could NYSERDA have done better to assist you in developing your product?

Research & Development Activities

16. During the course of the application process and the funding term, did the competitive landscape, either technically or commercially, change significantly enough so as to affect the relevance or importance of the project? If so, please explain.
17. Have there been any technical developments in your industry rendering your technology less or more advantageous? Please explain.
18. Have there been any commercial trends in the marketplace affecting the competitiveness of your technology? Please explain.
19. Were there any pivot points (major or minor) that were not originally planned during the funding/contracting process?
    a. If so, how did your research change as a result of these pivots?
    b. How was NYSERDA involved in the pivoting process?
    c. Were any pivots not permitted by NYSERDA? If so, please describe.
        i. If changes were not allowed by NYSERDA, how did that hinder the research?

Metrics & Benefits

20. Were jobs created at your company/organization as part of this project or in subsequent commercialization activities?
    a. If so, how many? Please describe.
    b. What percentage of these jobs are/were located in New York State?
    c. How many employees does your company/organization have at the present time? In NY State?
21. *[IF COMMERCIALIZED]* Can you please provide us with sales data for the product ($ & units sold)?
    a. Do you have any sales within New York State? Please describe.
    b. What percentage of your manufacturing was performed in NYS?
    c. Can you share any information on your expectations for future sales?
22. Did NYSERDA fund any product demonstrations as part of this project?
    a. Did these demonstrations result in energy savings? How much?

Concluding Questions

23. Are there any other benefits from this research that we have not discussed? If yes, please describe.
24. Has the development of this research led to any additional products or sparked new developments at your company?
    a. If yes, please describe.
25. We are hoping to speak with several employees/partners for each of the NYSERDA-funded efforts in our sample. Is there anyone else at your company/organization that we should speak with?
26. A subsequent phase of this research involves expanding our view to look at the overall R&D market for this technology (PV, wind, storage) and how NYSERDA's funding activities compare to broader development trends in project scope and timing.
    a. Is there anyone you've worked with either on this research or through your professional network that you think would be able to speak to the [insert tech area] market as a whole?

Appendix C: Non-Core Product Interview Guide

Interview Guide for CPTI Non-Core Technology Research Projects

Introduction:
NYSERDA has contracted with Energy & Resource Solutions, Inc. (ERS) and Industrial Economics, Inc. (IEc) to document success stories and lessons learned from projects funded by NYSERDA's Clean Power Technology Innovation (CPTI, also previously called Power Systems) program.
We have collected some initial information on __[*insert project name]*_____ from NYSERDA metrics data and publicly available information, and would like to confirm this information. This conversation should take no longer than 20 minutes.

1. Can you please describe the project funded by NYSERDA CPTI from your perspective and role?
    a. We've reviewed the NYSERDA program data but it would be helpful to hear from you the most important elements of the program and your role in the project.
2. What is the status of this project today?
    a. Has the project been commercialized?
    b. If so, what are your sales ($, units sold)?
        i. What percentage of sales are in NYS?
        ii. Can you provide information on your expectations for your future sales?
3. How many jobs were created for this project?
    a. What percentage of jobs were/are in NYS?
    b. How many people are employed by your company today?
4. How much funding did you receive from NYSERDA for developing this project?
5. Approximately what percentage of total available funds did the NYSERDA CPTI funding represent?
6. If you had not received this funding from NYSERDA CPTI, what would have been the impact on your research and development activities?
    a. What benefits besides funding did NYSERDA provide throughout the project?
    b. Has the development of this research led to any additional products or sparked new developments at your company?
    c. Is there anything that NYSERDA could have done better?