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Understanding the Complexities of Subnational Incentives in Supporting a National Market for Distributed Photovoltaics

Brian Bush, Elizabeth Doris, and Dan Getman
National Renewable Energy Laboratory

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Technical Report
NREL/TP-7A40-62238
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Prepared under Task No. SM13.1534

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Executive Summary

The number of subnational policies pertaining to photovoltaic (PV) systems has increased in recent years, and federal incentives are set to be phased out over the next few years. Understanding how subnational policies function within and across jurisdictions and influence PV market development informs policy decision-making. This report was developed for researchers and subnational policymakers to aid the analysis of PV system incentive functions in the emerging PV deployment market. The analysis is based on a "logic engine," a database tool that uses current state, utility, and local incentives[1] and allows users to see the interrelationships between PV system incentives and parameters, such as geographic location, technology specifications, and financial factors. Depending on how it is queried, the database can yield insights into which combinations of incentives are available and most advantageous to the PV system owner or developer under particular circumstances. This is useful for system developers to identify the most advantageous incentive packages for which they qualify, and for researchers and policymakers to better understand the national patchwork of incentives and how they drive the market.

The database was queried to identify the relative number and types of incentives at the subnational level. The logic engine identified the number of incentives for which consumers qualify and the subset of those that provide the largest monetary benefit, resulting in the "best" combination of incentives. The outcomes inform subnational policymakers about the range of possible combinations of incentives in their jurisdictions, and allow researchers and developers to compare incentives between jurisdictions. Primary findings from the initial analyses are divided into two categories:

- Descriptive statistics that summarize a large volume of PV incentive characteristics:
    - Approximately 72% of incentives listed in DSIRE (as of August 2013) are PV eligible.
    - The United States has 212 unique geographic areas of PV incentive applicability with the number of incentives in each area varying from one to seven. A different mix of incentives is available in each area.
    - Approximately 41% of subnational incentives include "special conditions" that restrict participation in the incentive program based on a factor within the incentive design (e.g., user must be in a specific club, system capacity) or as a result of that design (e.g., waiting lists). This indicates that generally speaking state, local, and utility incentives are being designed to target specific user groups or system types within specific jurisdictions. That is, niche or directed incentives make up a large proportion of the incentives available such that jurisdictions are designing policies that reflect their unique needs and goals.
- Overall findings related to the initial query:

[1] The PV incentives used are from DSIRE, widely considered to be the most comprehensive listing of U.S. policies and incentives.

- There is no visible strong correlation between the value of incentives and PV adoption given the data currently available to evaluate that question. This indicates that the relationship between incentives and market development demands further investigation if policymakers and program implementers are to better design programs and steward public money into effective programs. Areas of further investigation could include the development of a historically focused incentive and installed system dataset that would allow for temporal analysis and a better understanding of incentive impact over time.
- The number of incentives available varies dramatically by geography and consumer type. For residential customers, in nearly all locations, incentives are the least complex, meaning that the best combination of incentives does not vary with system capacity in kilowatt-hours or cost. For commercial, government, and nonprofit customers, about 80% of the locations have the same low complexity as residential customers, but 20% involve a range of best combinations of incentives (defined as those that reap the most financial benefit for the user of the incentive) that are determined by system cost and capacity. This finding indicates that government, nonprofit, and commercial sectors typically qualify for a wider variety of incentive options depending on their jurisdiction.
- PV system capacity and cost are the primary determinants of the type of incentives being classified in the best combination of incentives for a particular consumer at a given location. System capacity is a more important determining factor than cost, implying that policies are defined based on system capacity and are, perhaps inadvertently, leading consumers toward particular system capacities.
- While incentive benefits sometimes change with changing PV costs, which have been rapidly changing in recent years, the average benefit to a PV system varies as a function of incentive type: $0.25/W to $1.5/W from state grant programs, $0.50/W from state rebate programs, and up to $1/W from utility rebate programs, indicating that on average, state grant programs tend to offer the highest incentive benefits.
- The average benefit to a PV system varies as a function of incentive source: $0.25/W to $3.5/W at the state level, $0.25/W to $2.7/W from the utility, and $0.5/W to $1/W at the local level. This indicates that incentives reflect the financial capabilities of the jurisdiction and can differentiate localities in terms of marke competitiveness.

This report outlines these findings in detail, and further explores the potential for the use of the logic engine to better understand how incentives interact with the market to deploy solar technologies. These issues become more important as federal incentives taper off and the price of installed solar decreases. State and local policymakers, as well as utility program designers and implementers, need to be able to understand the impact of policy and programmatic changes to make informed decisions in a dynamic market.

List of Acronyms

DOE	U.S. Department of Energy
DSIRE	Database of State Incentives for Energy Efficiency & Renewable Energy
ESRI	Environmental System Research Institute
kW	Kilowatt
kWh	Kilowatt-hour
NREL	National Renewable Energy Laboratory
OWL	Web Ontology Language
PV	Photovoltaics
RDF	Resource Description Framework
W	Watt

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1 Introduction

State, local, and utility (collectively "subnational") entities are increasingly implementing clean energy policies, particularly as they apply to solar distributed generation. As of 2014, 29 states have adopted the Renewable Portfolio Standard, and 245 solar-qualified subnational incentive programs span 48 states, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands (DSIRE 2013).[2] These policies, implemented in parallel with rapid decreases in solar technology and installation costs (Feldman et al. 2013), contribute to a developing market for solar technologies in the United States.

Understanding how these policies drive the national photovoltaics (PV) market is a subject of a growing body of literature with multiple foci:

- The impact of individual policies on project, market, and economic development (see Hurlbut 2008; Couture and Cory 2009; Brown and Mosey 2008)
- The design of policies for optimal impact on project, market, and economic development (see Wiser et al. 2010)
- The evaluation of groups of policies, generally with limited regard to specific application context (see Krasko and Doris 2013)
- The evaluation of groups of policies at a specific location or groups of locations (see Steward et al. 2013).

This report provides an overview of currently available solar incentive trend data to inform the potential magnitude of PV technology market penetration in the United States. The "logic engine" database was used to inform the analysis. It was developed based on the 2013 data from the - Database of Incentives for Energy Efficiency & Renewable Energy (DSIRE) funded in part by the U.S. Department of Energy (DOE). The analyses establish distinct incentive application regions and evaluate how incentives in those regions function and impact the costs of solar projects. This allows incentives to be evaluated from two perspectives for policymakers:

- Analyzing individual effects of subnational policies as they are adopted within the policy environment
- Assessing the function of a group of subnational policies that contribute to the development of a PV distributed generation market technologies on a national scale.

Section 2 provides an overview of the methodology for creating the logic engine database that informs the analysis. Section 3 outlines findings from evaluating the sets of incentives and their impacts on PV system price and capacity. Section 4 discusses the findings and identifies additional applications of the logic engine database that could illuminate the impacts of simultaneously functioning subnational incentives on the emerging PV market deployment.

[2] The only unrepresented states are West Virginia and Wyoming.

2 Methodology

The methodology is based on the following primary activities:

1. Encoding the rules related to DSIRE incentives in a logic database for the purposes of increasing their analytic value in determining incentive impact on local market penetration and national trends
2. Determining the geographic applicability of each combination of DSIRE incentives
3. Estimating the qualification for incentives for a wide variety of system types and geographically dispersed customers.

Figure 1 illustrates the overall process of planning and conducting a sensitivity study, which aims to map the interaction of incentives with exogenous factors, such as geographic location, technology characteristics, and financial parameters. It also yields insights into the combinations of incentives that are available and most advantageous under particular circumstances.

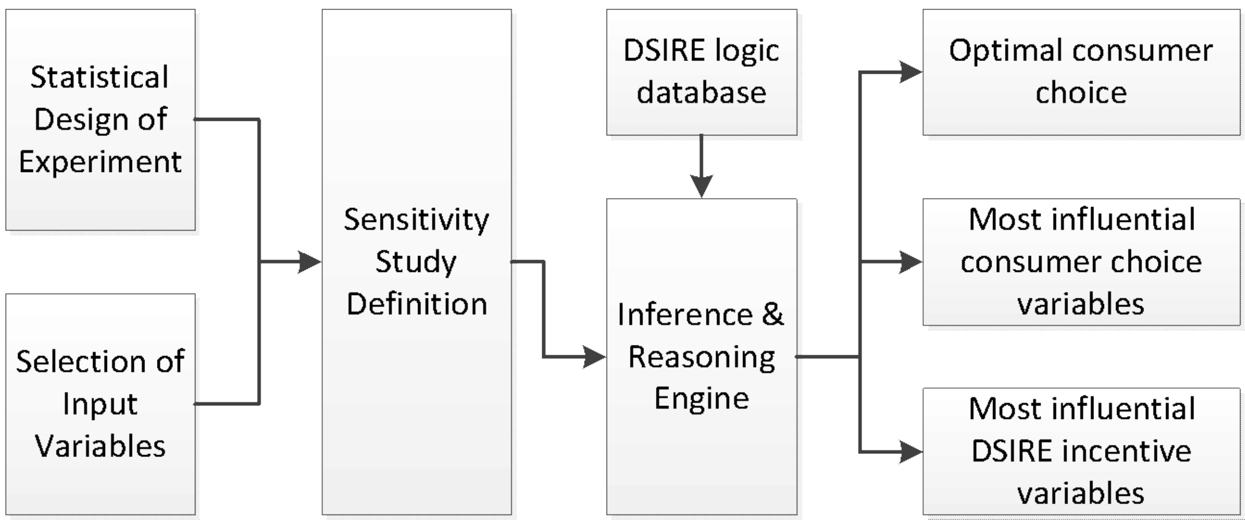

Figure 1. Methodology for DSIRE logic sensitivity study

First, incentive data from the DSIRE database were interpreted into a series of logic-based algorithms that can accurately respond to moderately complex queries about the applicability of particular incentive combinations under specific conditions. The logic database is encoded in the Resource Description Framework (RDF) (RDF Working Group 2013) using the Web Ontology Language (OWL) (OWL Working Group 2013) for representing relationships between data elements and Jena rules (Apache Software Foundation 2013) for specifying the mathematical logic needed to evaluate whether a particular customer installing a particular system at a particular location would be eligible for incentives. The source data describing the incentives were gathered from the DSIRE website (North Caroline State University 2013a), the DSIRE XML feed (North Carolina State University 2013b), and the quantitative spreadsheet of DSIRE incentives provided periodically to the National Renewable Energy Laboratory (NREL) (North Carolina State University 2013c).

The great advantage of RDF is that it can capture arbitrarily complex relationships between elements of information (see Figure 2) in a manner that can be queried and analyzed in software-based reasoning systems (namely logic engines). Encoding DSIRE involved decomposing each incentive into small, discrete, logical statements about aspects of the incentives, and using a precise, machine-readable vocabulary to make those statements. Table 2 summarizes these categories. For example, the statement that an incentive identified by the label “WA173F” has a feed-in tariff value of $0.17/kW for commercial PV would be encoded as the following subject-predicate-object triplet:

```
<http://dsirelog.nrel.gov/v6/nrel-data.owl#incentive_WA173F>
<http://dsirelog.nrel.gov/v6/nrel-data.owl#pv_com_fit_dlrs_kwh>
"0.17"
```

In this triplet, the URI “http://dsirelog.nrel.gov/v6/nrel-data.owl #incentive_WA173F” specifies that the incentive WA173F is the subject of the assertion, the URI “http://dsirelog.nrel.gov/v6/nrel-data.owl#pv_com_fit_dlrs_kwh” indicates which property of that subject is being asserted, and the value “0.17” provides the value of the property asserted. In this study the implementation of the DSIRE logic currently contains 73,812 RDF triplets of this sort and includes a comprehensive set of descriptive information, geographic relationships, and quantitative properties.

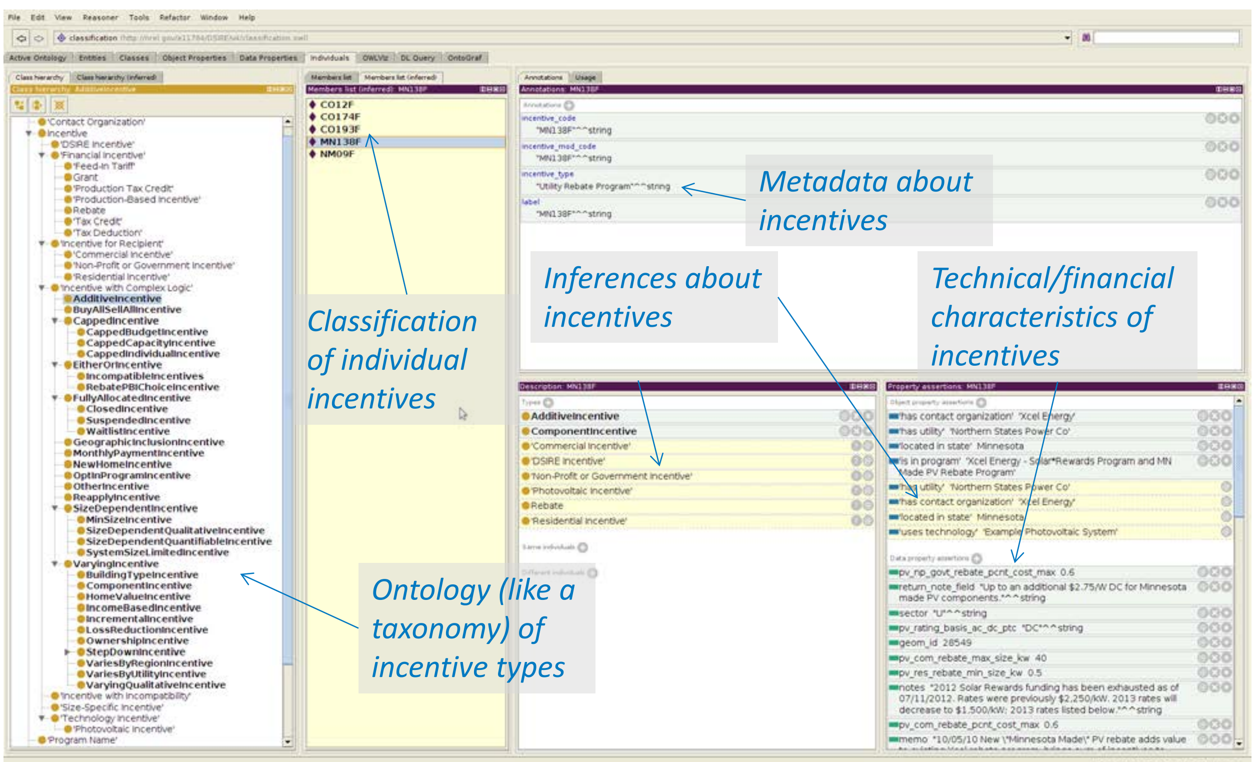

Figure 2. Example showing the encoding of incentive properties and relationships in RDF. The software tool used to display this information is Protégé

The quantitative spreadsheet from DSIRE describes the geographic applicability of each incentive by associating it with a parameter that indicates whether an incentive is applied at the federal, state, utility, or local level. One complication in this categorization involves incentives that are listed at the state level, but that have separate implementations for each utility. This complication was addressed by splitting these incentives into sub-incentives that represent each utility described in the incentive text, but retained as listed at the state level.

Because detailed utility boundaries are not freely available, the data used to describe these geographic regions were leased from Ventyx Research (Ventyx 2013). These data were further processed in two ways before geographies were assigned to incentives:

1. The utility boundaries were processed to remove "slivers," which are artifacts in the form of hundreds of small polygons created when two regions overlap imperfectly. These artifacts can occur where utility boundaries meet each other and/or they meet state boundaries.
2. The utility boundaries were joined to form state geographies that were then joined into a single national geography. This process resulted in a dataset composed of distinct incentive geometries at each sector with minimal errors at regional boundaries.

This dataset was then used to assign federal, state, and utility incentives to their respective geometries. Local incentives, for the most part, are associated with counties or urban areas. These geographies were selected from data purchased from Environmental System Research Institute (ESRI) (ESRI 2012) and then added to the master dataset depicting all the incentive geographies.

This master dataset contained hundreds of overlapping polygons, each of which described a geographic area in which a federal, state, utility, or local incentive could be applied. In an effort to bound the combinatorics of performing the analysis, this dataset was reduced to a form in which each polygon represented an area defined by a unique combination of applicable incentives. This was accomplished in a two-part process: a series of spatial intersections were performed with the intention of obtaining a set of polygons representative of all possible combinations of incentive areas. These polygons were then grouped by the sorted list of associated incentive identifiers and merged to form polygons that represented areas in which a unique combination of incentives could be applied. This final dataset represented a complete list of all potential incentive combinations available across the country. The total number of potential combinations of incentives was refined to a finite number (see Figure 3), which enabled an accurate estimate of applicable incentives at any location in the United States.

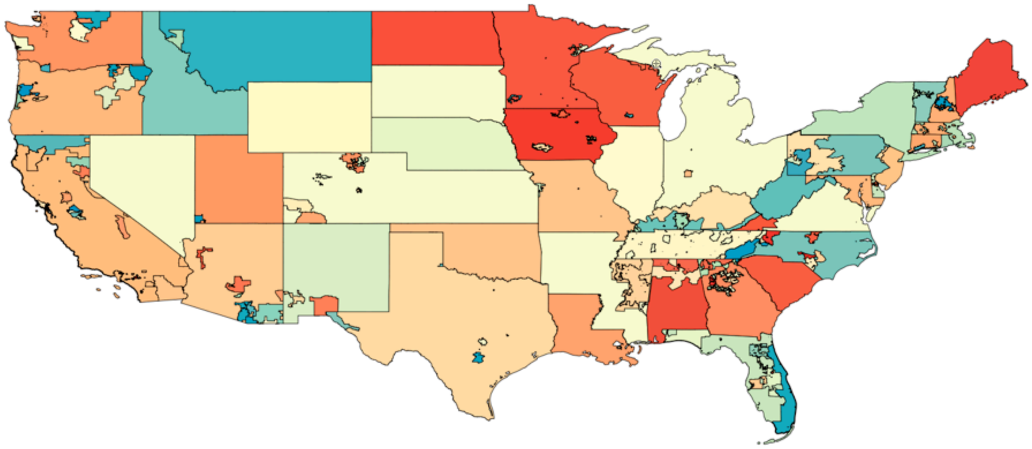

Figure 3. Boundaries of regions represent unique combinations of DSIRE incentives. The colors have no significance except to help the viewer distinguish the incentive regions.

To determine which combinations of incentives apply under different sets of conditions, approximately 1.3 million hypothetical customer and system combinations were generated with the following parameters specified:

- Customer type
  - Residential, commercial, governmental, nonprofit
- Customer geographic location
  - 212 areas representing unique combinations of incentives
- System capacity (kW)
  - Residential 2–10 (kW)
  - Commercial, government, nonprofit 10–250 (kW)
- System cost ($)
  - Residential 4–7 ($/W)
  - Commercial 4–6 ($/W)
  - Government, nonprofit 4 .5–6.5 ($/W)
- Capacity factor: an average capacity factor (Drury et al. 2013) was used for each region.

The frequency and values for these parameters were chosen according to joint probability distributions that loosely represent the prevalence of various PV systems in the United States. The logic engine database was then used to infer the combinations of incentives for which each customer or system is eligible and then to estimate the total or average monetary benefit. In this initial study, the monetary benefit was defined as the total expected undiscounted payment made by the incentive. More sophisticated studies involving discounted cash flows, payback periods, and other more complex criteria could be undertaken to meet different analytic needs. Additionally, the logic engine can handle special incentive-specific eligibility criteria such as those listed in Table 1.

Table 1. Special Incentive-Specific Eligibility Criteria

1	Customer type	a. Farm b. Non-corporate business c. Small business
2	Program membership	a. SNAP (WA) b. CCA (CA)
3	Income	a. Low income b. Moderate income
4	Third-party Power Purchase Agreement	
5	Lower income district	
6	Environmental justice district	
7	Natural disaster	
8	Housing type	a. Custom home b. Housing development c. “Standard solar” d. Affordable housing e. Multifamily
9	Housing efficiency	a. Efficiency measures implemented b. ENERGY STAR® home c. Approved by Maine Home Energy Savings Program
10	Housing value	a. Moderate home value
11	On-site energy need	
12	System area (square feet)	
13	System includes tracking	
14	System suboptimal tilt	
15	System ownership	a. Customer b. Third party c. Nonprofit
16	Equipment type	a. CEC listed equipment b. Equipment made in service territory c. Equipment made in state
17	Local installer	

Once the eligibility of all incentives and their expected benefits were computed, combinations of incentives that a customer could obtain simultaneously were determined. Because taking advantage of some incentives might exclude qualifying for others, a customer could concurrently obtain many possible groups of incentives or “baskets.” Some of these baskets have a higher total monetary benefit than others. The basket of compatible incentives with the greatest total benefit to the user represents the “best” combination of incentives for a particular type of customer and PV system configuration. The relative importance of assessing the value of incentive combinations varies based on the goals of the analysis. In this analysis, the best combination of incentives is assumed to result in the greatest monetary benefit to the consumer. All incentives do not necessarily appear in the best set of benefits for customers; some are suboptimal if the total undiscounted value of the monetary benefit is the criterion for placing it in the best set. This led to some incentives not qualifying for the best mix of incentives in a region. As such, a different definition on the part of the consumer (e.g., discounted cash flow or payback period), would probably change the best mix of incentives. The descriptive statistics of available PV incentives are discussed in Section 3.

3 Results

In August 2013, 245 active, PV-eligible incentives were listed in DSIRE. Most (234 or 94%) are either state based (75 incentives or 30%) or utility based (159 incentives or 65%), with relatively fewer federal, local, and other incentives (see Table 2). This breakdown of PV-eligible incentives by sector is expected from a policy development standpoint and as a result of data design in DSIRE. States and electricity distribution utilities outnumber federal government agencies, so the number of policies implemented by states and utilities is expected to be higher. Although the logic should apply to the local level, there are more localities, so more local policies are expected to be implemented. There are two potential limitations to this assumption:

- **Policy implication:** based on the data in DSIRE, local governments are less concerned about and/or able to support solar markets through incentive-based policies than are states or electricity distribution utilities.
- **Data limitation perspective:** DSIRE's scope is limited to incentives available in localities with large populations or considered by the database authors to be "especially innovative" (DSIRE FAQ 2013), meaning that it does not capture all available local incentives.

Table 2. Sources and Types of PV Incentives in the DSIRE Database

	Federal	State	Local	Utility	Other	Grand Total
Corporate Deduction		1				1
Corporate Tax Credit	1	21				22
Industry Recruitment/Support		1				1
Local Rebate Program			5			5
Performance-Based Incentive		5	1	48	3	57
Personal Deduction		1				1
Personal Tax Credit	1	22				23
State Grant Program		3				3
State Rebate Program		21				21
Utility Grant Program				1		1
Utility Rebate Program				110		110
Grand Total	2	75	6	159	3	245

DSIRE lists incentives for all jurisdictions as a mixture of production and investment incentives. More than one third of PV incentives require special conditions for eligibility that request information beyond basic customer and system characteristics—see Table 3 for a synopsis of the prevalence of these special conditions. Such special conditions likely have two distinct impacts on the pool of available incentives:

1. Target specific customers who can assist in meeting specific policy goals within jurisdictions (e.g., new home-specific incentives).
2. Increase the uncertainty in determining whether a customer deploying a PV system qualifies for an incentive that maintains a waitlist.

Table 3. Summary of Special Conditions for PV Incentives in DSIRE

	Corporate Tax Credit	Local Rebate Program	Performance-Based Incentive	Personal Tax Credit	State Rebate Program	Utility Rebate Program	Grand Total
Additive Incentive			1		1	3	5
Building-type based Incentive		1		1	6	4	12
Buy-all, Sell-all Incentive			2				2
Closed Incentive			2		1	3	6
Component based Incentive			1		1	3	5
Efficiency based Incentive				1		2	3
Home-value based Incentive					1		1
Incentive for New Homes					1	1	2
Incentive Varies by County			1				1
Incentive Varies by Utility					1		1
Incentive with Capped Budget	3		1	3		1	8
Incentive with Capped Capacity	1		1	1	1		4
Incentive with Choice					1	6	7
Incentive with Geographic Inclusion		5	2			1	8
Incentive with Incompatibility	15		5	13	4	4	41
Incentive with Minimum Area	1						1
Incentive with Minimum Investment	1			1			2
Incentive with Minimum Payment	1			1			2
Incentive with Monthly Payment						1	1
Incentive with System Cap	2			3	1	1	7
Incentive with Waitlist	2		1	1	1	4	9
Income based Incentive		1			1		2
Incremental Incentive		1			4	6	11
Load based Maximum Size Incentive			1		1	1	3
Maximum Size incentive with Complex Logic			2		2	1	5
Opt-in Incentive			4				4
Output based Rebate Incentive						2	2
Ownership based Incentive		1	1		1	2	5
Qualitative Size based Incentive			1			1	2
Qualitative Step-down Incentive			2		3	7	12
Qualitative Varying Incentive	1		3	2		1	7
Quantitative Size based Incentive	1		7	1	2	18	29
Quantitative Step-down Incentive			1		1	1	3
Suspended Incentive			2		1	8	11
Grand Total	15	5	14	15	13	40	102

At any geographic location, a PV system may qualify for a number of incentives depending on the type of customer, system capacity, and system cost. Systems might qualify for up to seven incentives, although residential and commercial customers generally have a broader range of qualifying incentives to choose from than do nonprofit and government customers (likely because of differences in taxation). This may indicate generally more organized and optimized incentive structures for residential and commercial customers and/or an increased number of options meeting the more varied needs of the residential and commercial sectors. In some cases, a customer might be able to simultaneously obtain several incentives for the same system (e.g., a federal tax credit, a state tax credit, and a utility rebate), but in other cases the selection of one incentive legally precludes the selection of another incentive for which the customer qualifies. The number of incentives in the best set that depend on customer type is depicted in Figure 4.

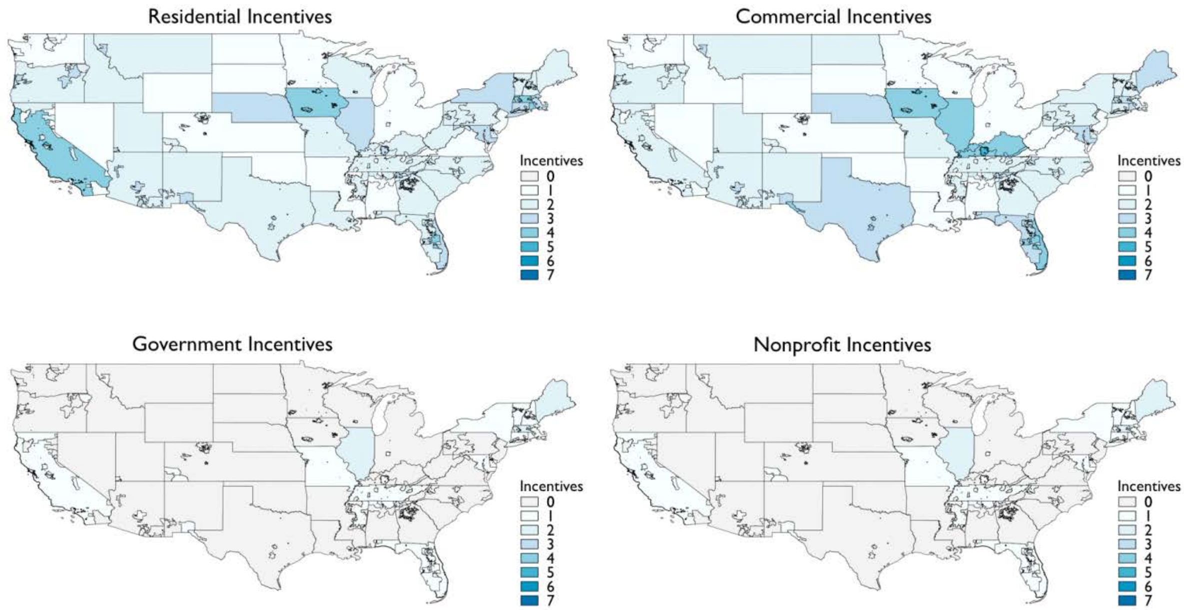

Figure 4. Number of incentives in the best set of qualifying incentives

The monetary benefits vary with PV system cost and capacity for typical systems, as shown in Figure 5. In many regions, the total benefit for residential and commercial customers is around $2/W, but in several localities; e.g., Oregon and Florida, this nominal value is substantially higher; benefits offered to governmental and nonprofit customers vary greatly by state. For example, in Delaware different sets of incentives qualify for the best combination, depending on system capacity, customer type, and system cost (Figure 6). The total benefit offered toward installing residential and commercial PV systems is constant in the range of $3/W on a per-capacity basis, but benefits offered toward installing governmental and nonprofit systems tend to diminish as system capacity increases.

The following patterns apply across the United States: The best combination of PV incentives is determined more often by system capacity than by system cost-per-capacity. Most geographic regions capture single best combinations of incentives, which are differentiated by system capacity, not by specific end use sector. In locations where a single best combination of incentives prevails, consumers can obtain this basket of incentives by selecting any system capacity and cost. For instance, residential consumers can choose the same combination of incentives that their neighbors choose. In cases with several unique combinations of best incentives, system-specific capacity and/or cost determine the optimal one. Nevertheless, Figure 7 indicates that the most valuable incentive of the mix of best incentives for particular system characteristics typically comprises most of the total value for governmental and nonprofit customers, but only about two thirds of the value for residential and commercial customers. This indicates that residential and commercial consumers may lose value if they only pursue the most valuable incentive, whereas governmental and nonprofit customers may opt to avoid the transaction costs of lower value incentives and not miss out on substantial financial benefit. The overall value of the benefit sometimes varies substantially depending on system configuration:

the total benefit can vary by several dollars per Watt, depending on system capacity and cost. In locations with this variability, it provides residential and commercial consumers (and to a lesser extent, government and nonprofit consumers) an opportunity to increase their benefits on a per-Watt basis, by selecting a system capacity and/or cost that maximizes payback. That is, the incentive may influence consumers to choose a specific system capacity. The fundamental sources of the variability in benefits are factors related to the design of incentives:

- If the maximum benefit is capped under the incentive, selecting a more costly system may result in a lower per-Watt benefit.
- If the incentive has a capacity cap or multiple capacity tiers, selecting a larger system may result in a lower per-Watt benefit.
- If net-metering or production is capped, selecting a larger system may result in a lower per-Watt benefit.

In Figure 9, we further break down sources of variations in terms of the type of incentive, the source of the incentive, and whether incentives with complex conditions are included. We see that the average range of benefit varies dramatically based on the type of incentive; corporate and personal tax credits vary less than \$0.5/W and performance-based incentives vary up to \$7/W depending on geographic location and system characteristics. The benefits of federal and local incentives tend to vary less than those of state- and utility-based incentives. Furthermore, based on the box-and-whisker plot, there is no apparent difference in the average benefit for "simple" incentives versus all incentives combined.

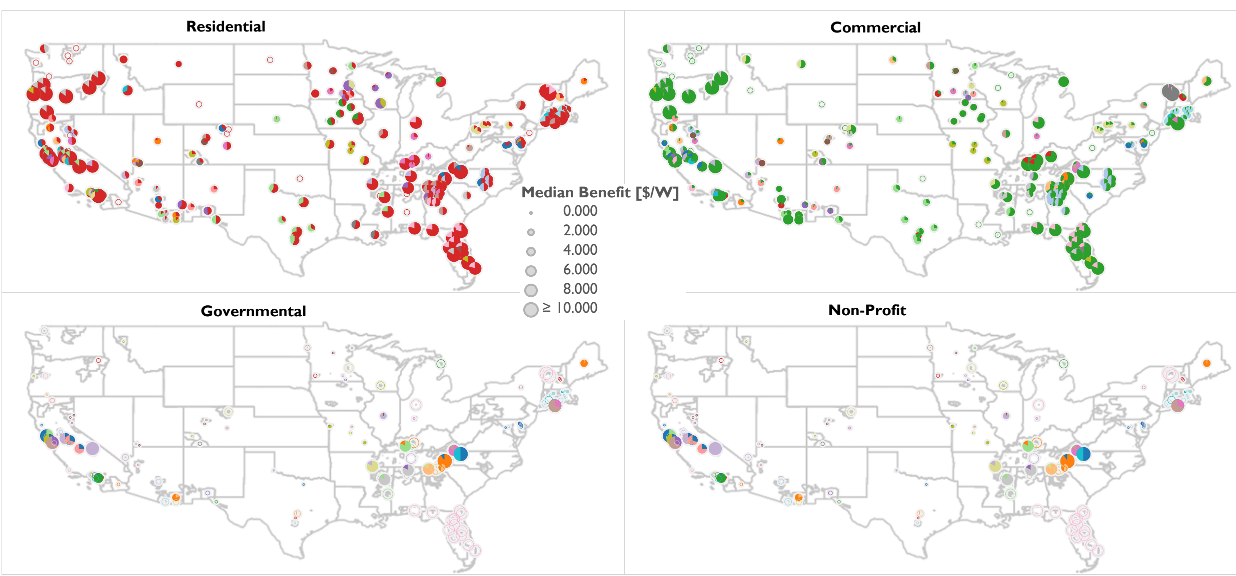

Figure 5. Median of total benefit, normalized by system capacity, for the best qualifying set of incentives. The size of the circles indicates the median total benefit. The colors in the pie charts indicate the amount of benefit arising from particular incentives.

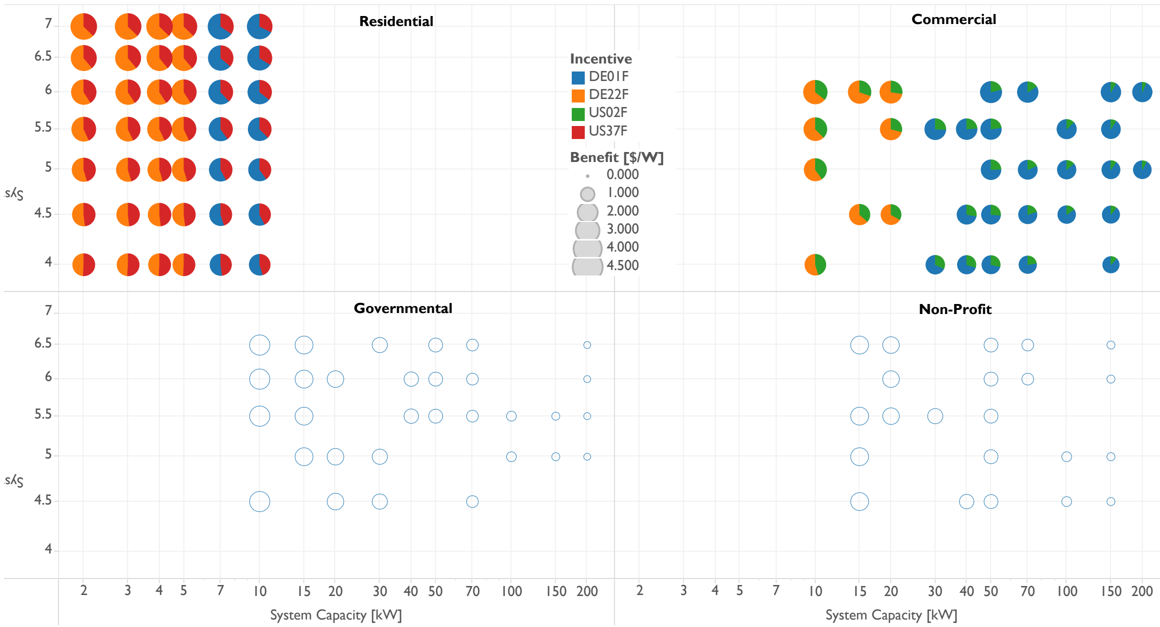

Figure 6. Best combinations of qualifying PV incentives in Delaware, as a function of customer type, system capacity, and system cost

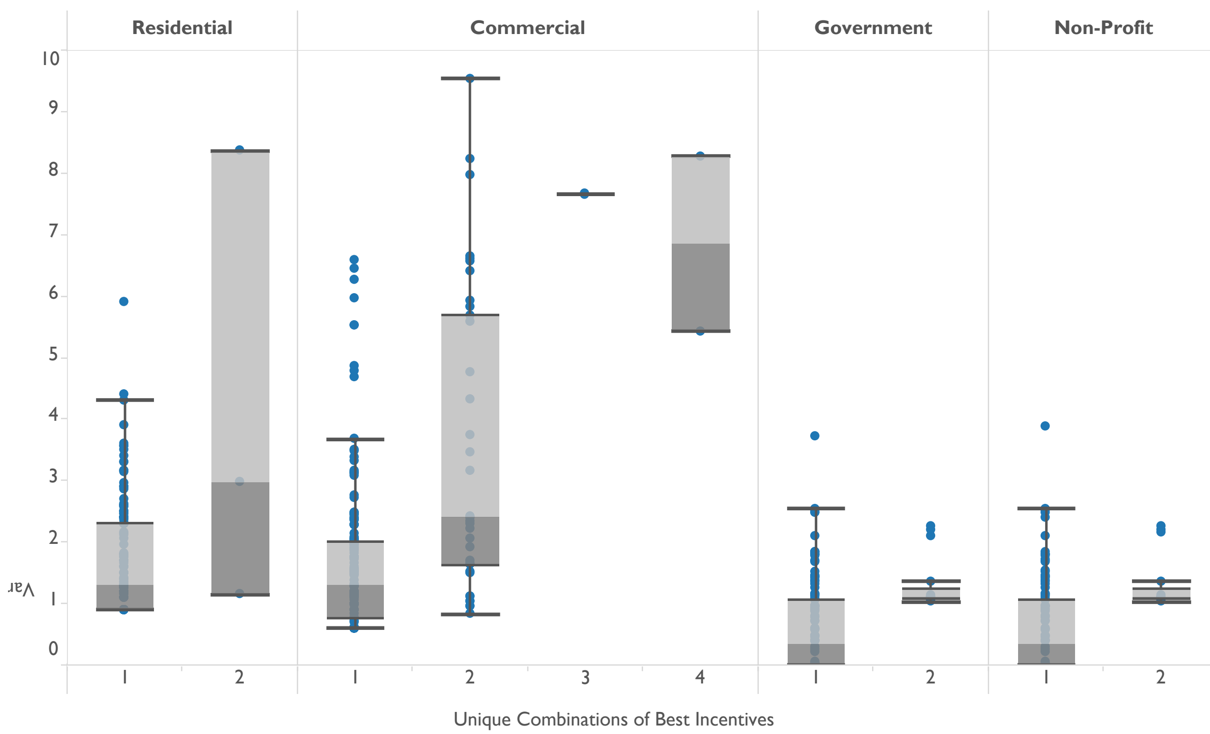

Figure 7. Variability in the benefits of the best combination of incentives. In this box-and-whisker plot, the second quartile of the distribution is shown in dark gray, the third quartile in light gray, and 5%/95% quartiles as black bars.

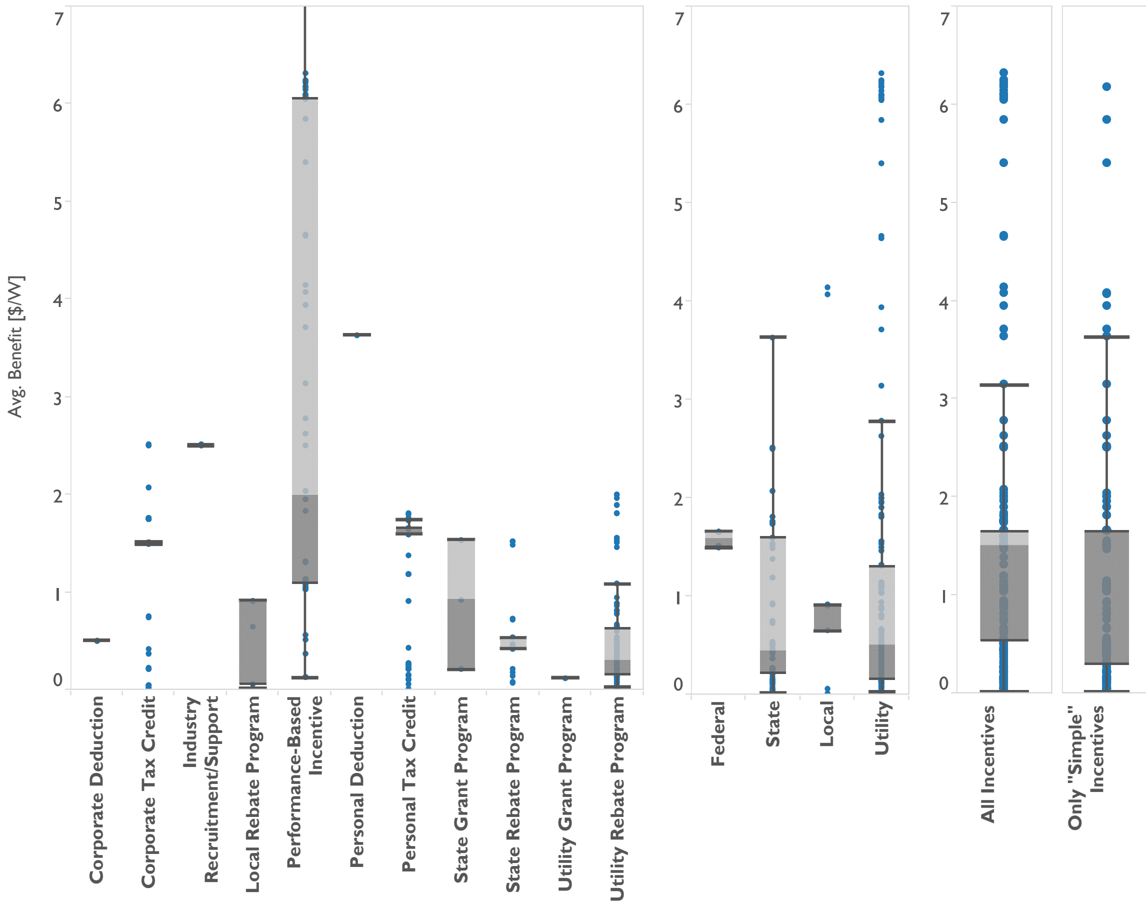

Figure 8. Variability of incentives as a function of incentive type, source of incentive, and whether incentives with special conditions are excluded. In this box-and-whisker plot, the second quartile of the distribution is shown in dark gray, the third quartile in light gray, and 5%/95% quartiles as black bars.

Finally, correlations between self-reported PV adoption data (NREL 2014) and the level of DSIRE-reported incentives in the geographic region were evaluated. Exploratory analysis of these data, both at the county and at the point level of resolution, did not indicate a strong correlation between the value of incentives and PV adoption. There are hints of slight positive trends in per-capita PV adoption as a function of the magnitude of incentive benefits, but the data quality limitation of the self-reported data, incompleteness of DSIRE's subnational data, and time differences between promulgation of incentives and installation of PV systems confound causal relationships between incentives and adoptions in these datasets. However, a thorough and careful analysis that includes models for biases in these data and that accounts for the temporal variations might unearth niches where incentives are strongly correlated with adoption.

4 Discussion and Conclusion

"Subnational" entities are increasingly developing and implementing clean energy policies, particularly with reference to solar distributed generation. The foregoing analysis, based on the logic engine, is intended to be a data-driven beginning to analysis on the functioning of subnational policies in their jurisdictions to inform policymakers' analysis on the market for PV deployment. This initial analysis focuses on identifying patterns within PV incentives data at the subnational level across the United States. Five major areas related to the functioning of PV incentives as applied to customer use are discussed.

Overall, the numbers and types of incentives that consumers can consider in project development decision-making vary. Much of the variability is tied to geography, type of consumer, and special conditions placed on incentives. A three-stage decision process in consumers' assessment of incentives is assumed:

1. Determine for which incentives the consumer and system qualify.
2. Analyze the value of the incentive to the specific consumer.
3. Capture the value of the incentive through application and reception.

Each stage in the decision process presents challenges to the consumer in determining qualification, estimating benefits, and optimizing payback, respectively. At this time, the database created by the logic engine is not publically accessible, but this capability could be pursued in a future area of research.

First, at each stage of the decision process, a consumer may consider a multiplicity of incentives depending on where a project is located. The logic engine reported 212 distinct geographic areas in the United States to which PV incentives are applicable. In these places, a consumer may consider a unique mix of up to seven subnational incentives. Although there are geographic hot spots (e.g., California) where seven incentives might apply, it is more common for three incentives to be potentially applicable to a project. In some cases, the consumer may qualify for up to seven incentives, but is legally constrained from claiming all simultaneously. The best legally allowable combination of incentives—defined as the total undiscounted payment from the incentives—usually contains up to four incentives.

Second, the number and type of incentives available to the user varies dramatically by geography and type of consumer. In nearly all locations residential customers can qualify for the best combination of incentives that is unique and does not vary with system capacity or cost. Thus, residential consumers in a region with a single best combination of incentives can apply for the same mix of incentives as their neighbors, regardless of differences in system cost and capacity. The same logic as for residential customers applies to about 80% of locations for commercial, government, and nonprofit customers, but 20% involve a different range of best combinations of incentives based on system cost and capacity. This indicates that the commercial, government, and nonprofit sectors sometimes have a wider variety of options available.

Third, PV system capacity and cost primarily determine which incentives are in the best combination for a particular consumer type at a given location (capacity is a more important determining factor than cost). That is, policies are defined based on system capacity and potentially suggest consumers adopt particular capacity of systems. In Delaware, the total benefit from a PV system was highest from a 10-kW system capacity regardless of system cost for government customers; the highest benefit for nonprofit customers was from a 15-kW system regardless of system cost.

The estimated benefit of the best combinations of incentives varies, on average, by more than $1/W for residential and commercial customers, depending on system capacity and cost, but less than $0.5/W for government and nonprofit customers. The variability in estimated benefit is greater in locations where the customer might be eligible for a range of best combinations of incentives, depending on system characteristics. On average, system cost is a more influential factor than system capacity in estimating monetary benefit.

Fourth, most of the variability (and thus, uncertainty) in per-Watt benefit arises from special conditions, such as system capacity, or production caps that are built into incentives. Special conditions, if present, increase the variability in estimated payback. More than one third of PV incentives have such special conditions for incentive eligibility that require information beyond basic customer and system characteristics. Some incentives involve caps on budget, set a capacity requirement, or maintain waiting lists. Others involve customer characteristics (e.g., income or membership in a group) or PV system characteristics (e.g., type of installer). Understanding the impacts of these special considerations that limit the applicability of incentives on the local and subsequently, national PV market is beyond the scope of this initial study, but is feasible with the current data structure.

Fifth, a handful of incentives never appear in the sets of best combinations of incentives because other options are more viable in terms of their benefits and availability. One interpretation is that these incentives are not optimized and could be extraneous; it is equally or more possible that this is a factor of the definition of *best* used in this analysis. A different definition on the part of the interested consumer (e.g., discounted cash flow or payback period), would probably change the mix of primary incentives. Providing for a wider range of definitions of best incentives to generate more possible incentive combinations to inform local or national policymaking is a possible next step for further research.

These five outcomes explain the function of incentives and their dependence on parameters, such as geographic location, and represent the initial findings from the logic engine database. Increasing subnational leadership, as measured by an increasing number of subnational policies for PV, indicates that further understanding how these policies could interface or interfere with each other and/or with federal incentives, can inform local policy development and potential impacts on a national patchwork of policies. This is beyond the scope of this initial evaluation; however, several priority areas could be examined in future studies.

A multitude of questions can be evaluated with the logic engine about whether PV incentives facilitate the PV market for deployment on a national scale. That analysis would be possible with the data available in DSIRE and the OpenPV database (http://openpv.nrel.gov/), the most comprehensive list nationwide of crowd-sourced PV installations; however, additional detail in both systems would provide more accurate results. A comprehensive list of local and utility incentives is needed and would increase the resolution and accuracy of this analysis. The data on the current status of PV installations are available from OpenPV database, but this database has limitations related to the data being generally self-reported. Increased data collection and validation of systems would improve such an analysis.

Another opportunity is to examine "special considerations" in policies as a way of identifying the impacts of local design priorities on the development of a national PV market. This type of analysis would help policymakers assess the intended applications of policies in different parts of the country and then observe their impacts on PV technology adoption. For example, if it could be shown that the incentives in one region or state specifically reward high system cost, because the system was purchased locally or installed using a specific technology, a correlation could be made between those incentives and the types of systems that are installed in that region. Once this relationship is better understood, it could be used to help subnational policymakers develop policies that focus on coordinated support for a particular aspect of the technology based on parameters such as system cost and capacity.

These suggestions contain assumptions about how specific aspects of a policy could impact PV system adoption. These assumptions are often used in policy decision-making, but are not fully understood. To determine the impact of a policy change on PV system adoption, the assumptions would need to be quantified and validated against historical data. Further, changes in the policy mix could be modeled and projected impacts of subnational policy changes could be applied to the national PV market. This model would serve as collective knowledge to policymakers to help them formulate national and regional renewable energy adoption strategies to increase the level of PV system market penetration on a national scale.

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