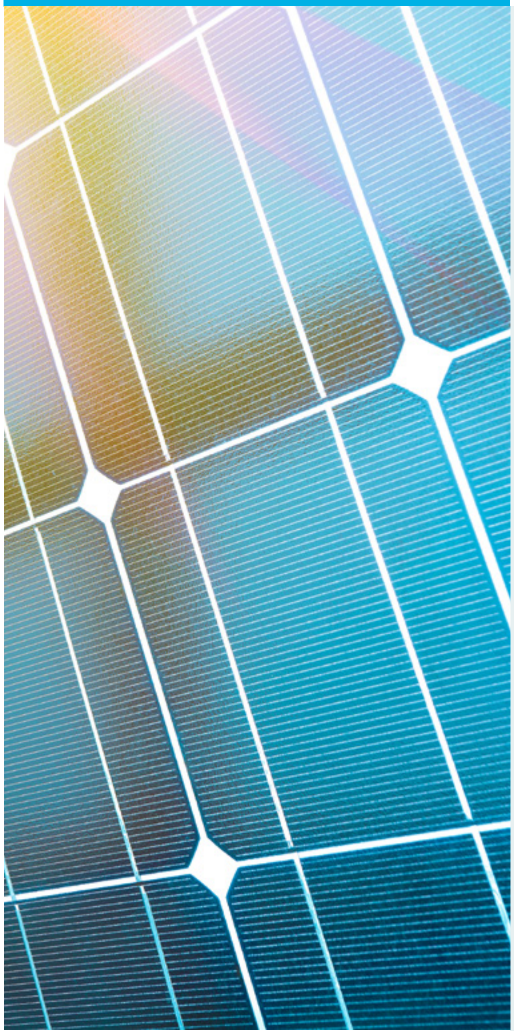
White Paper

# DER Optimization: Cost-effective Utility Solutions with Energy Efficiency, PV, and Storage

*By Haider Khan and Hameed Safiullah, ICF*



## Shareables

- It is critical for utilities to devise approaches to help manage the proliferation of distributed energy resources (DERs) in the system.
- DSM high performance new homes program (HPNH) can easily transition to DER HPNH programs that include solar with Energy Efficiency (EE).
- Integrated analysis essential to assess interaction of multiple DERs and create the DER HPNH program design.
- ICF has an integrated analysis framework to identify optimal configuration of DER.

## Executive Summary

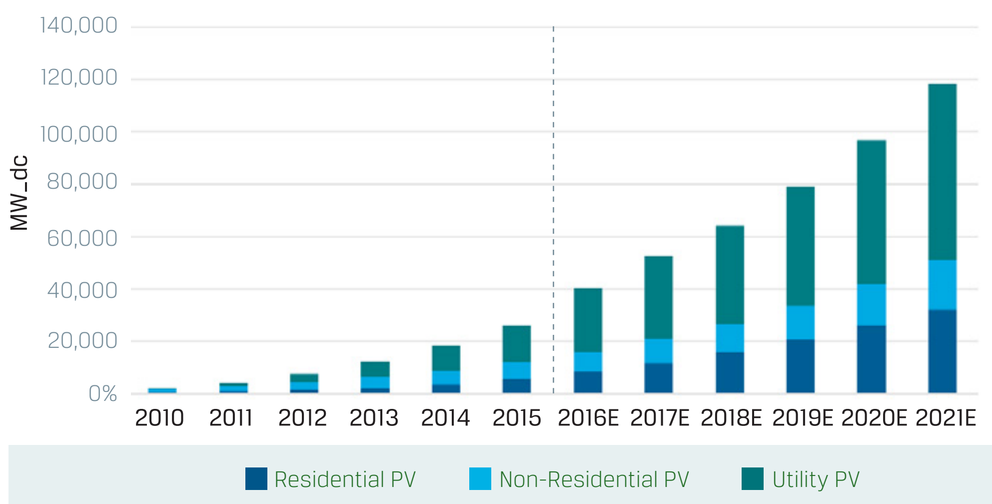
The growth of distributed energy resources (DERs) has led to a paradigm shift in the electric power system. Traditionally, the energy flow was uni-directional—from the generation stations to the load centers. The model of uni-directional energy flow is transforming towards a more multi-directional flow due to the growth of DERs with little predictability of their placement. ICF has developed an integrated analysis methodology to identify the cost-effective configuration of DERs to serve customer demand and serve the utility bottom line. The methodology uses building energy simulation software in combination with a mathematical optimization procedure to identify cost-effective configuration of resources. The analysis will be instrumental in aiding utility sponsored program development which in turn would influence DER growth towards locations with greater benefits in the system for all parties. The overarching goal is to optimize for customer savings while maintaining a reasonable utility cost-effectiveness metric.

## DERs Approaching the Tipping Point

Solar photo voltaic (PV) installations in the U.S. have reached 27,500 MW in Q1 2016.[1] As Federal Investment Tax Credit for (ITC) solar was extended, solar growth is projected to be >72 GW[2] from 2016-2020 (Exhibit 1). Some of the key drivers for the growth of PVs are net-metering, feed-in tariffs, investment tax credits (ITC), production tax credits (PTC), renewable energy credits (RECs), and Solar Carve-outs. The current national average installed cost of a 5 kW residential rooftop system is around $16,000[1] and a 500 kW commercial rooftop system costs around $950,000.[1] In addition to residential solar PV, community solar pilots and programs are expected to increase in 2016.

In addition to solar PVs, the energy storage market is also expected to experience a significant growth in the coming years. The installed base of energy storage in 2016 is around 464 MW most of which is utility scale (75%).[3] However, commercial and residential solar PV, paired with batteries, are gaining traction with major solar firms announcing only rooftop solar and battery bundled solutions will be sold by 2018. The current cost of a 10 kWh lithium ion battery ranges from $4,900 to $12,000[4] and the cost is expected to drop significantly in the coming years.

EXHIBIT 1. U.S. HISTORICAL AND FORECASTED PV INSTALLED CAPACITY




Source: GTM Research, ICF

[1] U.S. Solar Market Insight Report 2016 Q2, GTM Research & SEIA.org

[2] Impacts of Solar Investment Tax Credit Extension, SEIA.org, http://www.seia.org/research-resources/impacts-solar-investment-tax-credit-extension

[3] Department of Energy—Energy Storage Exchange database

[4] Levelized Cost of Storage Analysis—Version 1.0, Lazard

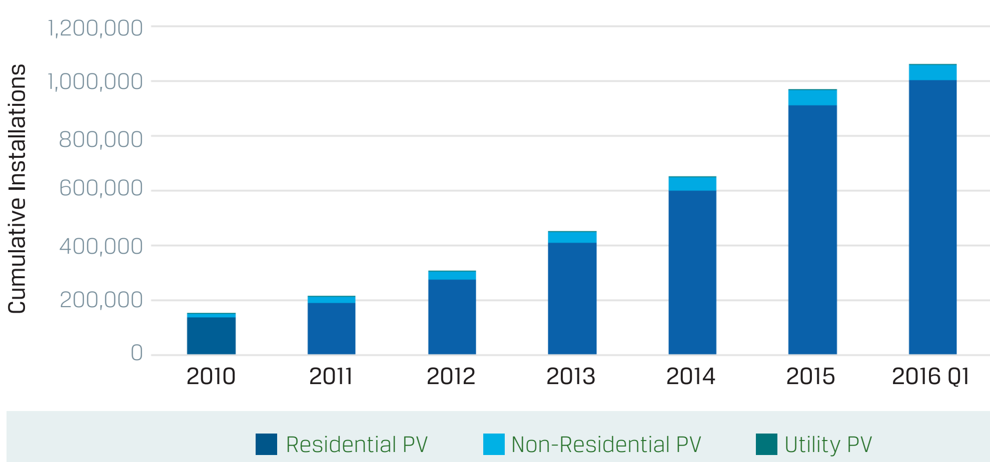
## Impact of Random Installations of DERs

As solar PV is expected to grow in the coming years, an important consideration is the location of resources on the grid. Residential solar PV installations are expected to exceed 1 Million by 2016[1] (Exhibit 2). The distribution grid plays a crucial role in accommodating DERs and facilitating the interaction with the grid. Therefore, it is imperative for utilities to assess the impact of increased DERs to ensure the reliability of the distribution system (Exhibit 3).

Increasing amounts of DERs in the power grid would have significant impacts on distribution system planning and operation. Systematic planning for accommodating DERs can have far-reaching positive impacts such as capital deferral, increased grid resiliency, peak reduction, and power quality support. The distributed and heterogeneous characteristics of DERs have led to several complex interactions in the distribution system. Utilities and regulators across the U.S. are developing processes and roadmaps to address these complexities. Regulatory proceedings such as CA Distributed Resource Planning (DRP) and NY Distributed System Implementation Plan (DSIP) have initiated the development of analysis methodologies such as hosting capacity and locational value analysis for effective utilization and deployment of DERs. Similar novel analysis methods are required to mitigate the adverse effects of uncontrolled growth of DERs.

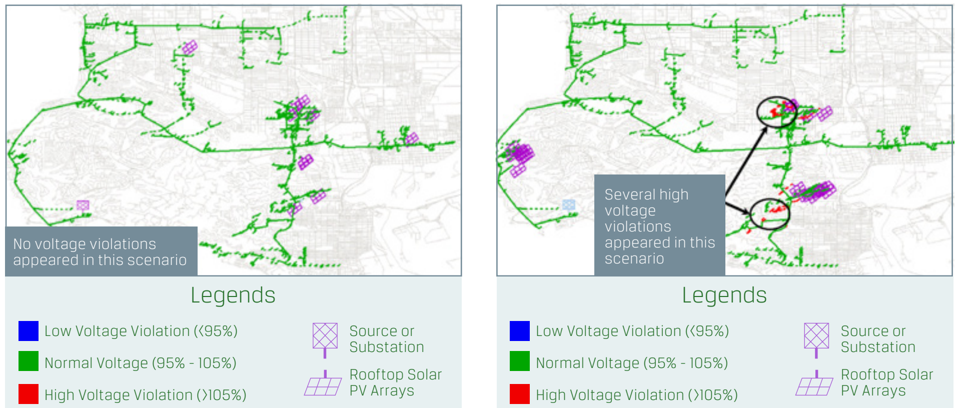
In most cases, installations of PVs are based on limited incentives and net metering. Providing the right incentives would help in developing DERs in locations with greater benefits. The utility must be capable of analyzing the grid and providing effective solutions and incentives to customers based on system benefits. Thus, utility programs that are designed for targeted penetration of DERs are essential to leverage the full capability of DERs.

EXHIBIT 2. HISTORICAL NUMBER OF SOLAR PV INSTALLATIONS




Source: GTM Research

EXHIBIT 3. DISTRIBUTED PV INSTALLATION—NO VIOLATIONS (LEFT); CONCENTRATED PV INSTALLATIONS CAUSE VOLTAGE VIOLATIONS (RIGHT)




Source: ICF

## Integrated Analysis Approach

The advancements in distributed energy resources and demand-side technologies have led to a complex array of options for serving the electricity demand of customers. However, most current demand-side management programs don't consider DERs when determining the optimal mix of technology options to serve customer demand. Besides administration issues, this is also because, to identify the cost-effective configuration of technology resources, an integrated analysis framework is required for assessing the tradeoffs and combinations that occur due to the interaction of multiple technologies, which was not available until recently. In the past, using a similar framework,[5] ICF has worked with utilities to design prescriptive high performance new residential construction programs that are optimized for energy efficiency. But to include DER in the technology mix, an enhanced integrated analysis framework for designing DER programs was developed. This is necessary because the DER package of interest includes energy efficiency, solar PV, and energy storage. Each of these DERs have unique characteristics with respect to energy provision and modification which require an integrated approach to assess the trade-offs and interactions. For instance, the combination of solar PV and energy storage alleviates the time of day concerns of solar PVs. Further, as energy efficiency is typically the most cost-effective of the DER options, including energy efficiency helps in making the overall program cost-effective.

The integrated analysis framework uses building energy simulation software in combination with a mathematical optimization procedure to identify cost-effective configuration of resources. The energy modeling tool simulates the interaction of DERs with the system demand. The operational characteristics and costs of the simulation are fed into an optimization model that analyzes and

[5] IBPSA Publication

searches the feasible region for an optimal solution that fulfills all constraints. A benefit-to-cost ratio (BCR) cost-effectiveness calculation is performed at every iteration to ensure the cost-effectiveness constraints are fulfilled.

This framework is instrumental in aiding utility-sponsored program development which in turn would influence DER growth at locations with benefits on the system. A variety of goals and constraints can be defined in this framework for the DER program design, including maximizing peak demand or energy savings, increasing system load factor, and minimizing the incremental cost of construction, therefore, minimizing incentive requirement.

## DER Optimization

A DER optimization of customer savings with the constraint of utility cost-effectiveness staying positive can be used to find optimal measure packages for specific locations. The measure package consists of a combination of energy efficiency, solar PV, and energy storage. Customer savings are calculated based on energy consumption savings over 25 years, while the utility cost-effectiveness is evaluated by looking at peak load savings and overall energy consumption reduction. The inputs, processes, and outputs for the DER optimization are depicted in Exhibit 4.

EXHIBIT 4. OPTIMIZATION FRAMEWORK

| | |
|---|---|
| INPUTS | ■ Energy efficiency measures |
| | ■ Solar PV and behind the meter residential energy storage options |
| | ■ Program location |
| | ■ Cost structure (Fixed or TOU) |
| PROCESS | ■ Simulate and calculate the savings for different measure packages |
| | ■ Constrain the measure package and evaluate the criteria |
| | ■ Re-simulate if criteria are not met |
| OUTPUTS | ■ Locational optimal measure package (potential combination of EE + PV + ES) |
| | ■ Potential customer savings using the optimal measure package |
| | ■ Utility cost-effectiveness metric |

Source: ICF

## Optimized New Residential Construction DER Program Design

Scenarios were run for utilities in Texas and Maryland with the DER optimization tool. These include scenarios with Time of Use (TOU) rate structure to realistically assess the advantage for behind the meter energy storage. The optimized measures for the prescriptive package that results in most cost savings while ensuring cost-effectiveness are shown in Exhibit 5 with the resulting savings shown in Exhibit 6.

EXHIBIT 5. DER OPTIMIZATION RESULTS SHOWING SOLAR PV AND EE MEASURES

| Measure Name | Baseline – IECC 2009 Code | Optimized DER (EE + PV) Program Design – Texas | Optimized DER (EE + PV) Program Design – Maryland |
|---|---|---|---|
| AC Unit SEER | 14 | 18 | 16 |
| Lighting | 50% CFL | 90% LED | 90% LED |
| Window U-Value | 0.65 (TX), 0.35 (MD) | 0.25 | 0.28 |
| Window SHGC | 0.3 (TX), 0.4 (MD) | 0.25 | 0.28 |
| Ceiling Insulation R Value | 30 (TX), 38 (MD) | 38 | 38 |
| Wall Insulation R-Value | 13 | 18 | 18 |
| PV System Capacity (kW) | NA | 3 | 2 |

EXHIBIT 6. PRESCRIPTIVE OPTIMIZED NEW RESIDENTIAL DER PROGRAM SAVINGS

| | Optimized DER (EE + PV) Program Design – Texas | Optimized DER (EE + PV) Program Design – Maryland |
|---|---|---|
| Customer Savings (NPV – 25Years - 3% discount) | $7,535 | $4,995 |
| Cost to Benefit Ratio (PAC) | 1.5 | 1.5 |
| Annual Energy Savings (kWh) | 6,671 | 4,332 |
| Peak Demand Savings (kW) | 1.14 | 0.77 |

In all the scenarios that were run for the two states, including residential TOU rate structure, energy storage was not cost-effective. The reason was that with the current TOU rates that are in place, the assumed principal cost of $929/kWh was high. However, even at this cost, in other jurisdictions that have different underlying program characteristics, such as higher avoided costs, it may be cost-effective. As behind-the-meter residential energy storage is of interest to many stakeholders, further analysis was conducted to determine the break-even cost of energy storage that will make it cost-effective for the selected TOU rate structure. In Texas, the break-even cost was $836/kWh while in Maryland it was $607/kWh. Using recent market price forecasts, the break-even point will be reached in Texas in 2-3 years, while in Maryland it may take 4-6 years.

## Conclusion

The growth of distributed energy resources is transforming the electric power system towards a more multi-directional flow but with little predictability and control over placement.

ICF has developed an integrated analysis framework to identify the cost-effective configuration of DERs that can be packaged as a utility-sponsored prescriptive DER program optimized to meet the goals of the utility and offer savings to the customer, and can influence DER growth towards locations with greater benefits in the system. Due to the large number of DER technology options, varying goals, and constraints, the integrated DER analysis framework is necessary to identify the optimal measure packages. This framework can also be applied to other DER technologies, such as CHP micro turbines, fuel cells, and residential wind turbines.

Using the integrated analysis framework, a few scenarios were run for a utility in Texas and Maryland. The results show that a combination of energy efficiency and solar PV are currently the best option.

This framework is currently being expanded to create optimized prescriptive DER program designs that take into account locational value, capital deferral, and cost-effectiveness of non-wire alternatives in feeders that are congested.

### About ICF

ICF (NASDAQ:ICFI) is a global consulting and technology services provider with more than 5,000 professionals focused on making big things possible for our clients. We are business analysts, policy specialists, technologists, researchers, digital strategists, social scientists and creatives. Since 1969, government and commercial clients have worked with ICF to overcome their toughest challenges on issues that matter profoundly to their success. Come engage with us at **icf.com**.

## Author Bios

**Haider Khan** has 13 years of experience in econometric and energy modeling, simulation, and optimization for utility analytics including demand side management, energy efficiency, and renewable energy. Mr. Khan leads ICF's Energy Efficiency Analytics and Policy team which conducts residential, commercial, and industrial energy modeling; data analytics; econometric modeling; software development for energy savings estimation; and DSM program implementation support.

Mr. Khan earned his B.S. in Mechanical Engineering from University of Engineering & Technology, Lahore and his M.S. in Mechanical Engineering from Oklahoma State University.

**Hameed Safiullah** has over 5 years of experience in energy system modeling, renewable resource integration and electricity markets research. At ICF, Dr. Safiullah's work is focused on evaluating the impacts of distributed generation resources on the power grid. He specializes in power system economics, energy system modeling, optimization, and data analytics. He is currently working on locational value analysis of distributed energy resources.

Dr. Safiullah earned his Ph.D. in Engineering and Public Policy from Carnegie Mellon University and his M.S. in Industrial Engineering from Purdue University.

For more information, contact:

**Haider Khan**
haider.khan@icf.com +1.703.934.3868

**Hameed Safiullah**
hameed.safiullah@icf.com +1.703.713.8767