Impacts of Solar-Export Credit Rates on Solar Deployment, Utilities, and Customers

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National Lab Technical Workshop on Distributed Solar Grid Impacts
Utah Public Service Commission Docket No. 17-035-61
July 11, 2019

This work was funded by the U.S. Department of Energy Office of Electricity, under Contract No. DE-AC02-05CH11231.
Outline

1. General impacts of solar-export credit rates
2. Grid exports and strategies for managing exports
3. Battery storage economics for managing grid exports
NEM Reforms: Motivations and Impacts

Motivations
- Grid Integration Challenges
- Inefficient Price Signals
- Cost-Shifts & Utility Financial Health

Impacts
- PV Adoption
- Technology Innovation
- Utility Financial Metrics
NEM reforms come in many shapes and sizes

**Changes to underlying rate design**
- Increased fixed charges
- Demand charges
- Locational pricing
- Time-varying pricing
- Minimum bills

**Changes to/replacement of NEM**
- Export Credit Rates (Net Billing)
- REC ownership rules
- Buy-all/sell-all
- Standby charges
Implications of NEM reforms differ for residential vs. non-residential customers

<table>
<thead>
<tr>
<th></th>
<th>Compensation under Standard NEM</th>
<th>PV Output Relative to Load</th>
<th>Coincidence between PV and Load</th>
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</thead>
<tbody>
<tr>
<td><strong>Residential</strong></td>
<td>Relatively high, Reflects average cost of service</td>
<td>Relatively high, PV often sized to meet 75-100% of annual energy consumption</td>
<td>Relatively low, Class-level peak often occurs in early evening</td>
</tr>
<tr>
<td><strong>Non-Residential</strong></td>
<td>Relatively low, Closer to utility’s short-run marginal costs (because of 3-part rates)</td>
<td>Relatively low, Often constrained by available roof-space</td>
<td>Relatively high, Class-level peak often occurs in early afternoon</td>
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**Bottom line:** The transition from standard NEM to grid-export rates may be fairly inconsequential for many non-residential customers.
Utility Financial Impacts of Standard NEM (which grid export rates might potentially mitigate)

- Earlier LBNL study that modeled the effects of net-metered PV on a Southwest IOU generally found that it:
  - Reduced shareholder ROE and earnings
  - Increased average retail rates
  - Depending significantly on specific conditions (e.g., deferral value, decoupling, etc.)

- Net billing will tend to reduce those effects, depending on:
  - Delta between grid export and retail rates
  - Level of grid exports
  - Impacts on PV deployment levels

Modeled Impacts of Full NEM for a SW Utility
Percentage change from no-PV to 10% PV

PV Deployment Impacts from Moving to Grid Export Rates

- Used NREL’s dSolar model to project aggregate U.S. distributed PV adoption under two alternate scenarios
  - Full NEM at retail rates
  - Grid exports compensated at regional wholesale prices
- Compared to full NEM, deployment is 55% lower for residential and 20% lower for non-residential customers
- Assumes static technology and system design

Projected Total U.S. Distributed PV Deployment
Full NEM vs. Grid Exports at Wholesale Prices

Outline

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Interdependence of Export Price and Quantity

- Impacts of export credit rates depend on both export price and quantity
- Net billing structures incentivize reduced grid exports
  - West-facing roofs
  - Smaller system sizes
  - Load shifting
  - Storage
- The greater the price differential between retail and grid export rates, the greater that incentive

LBNL Analysis of Grid Exports

Data and Analysis Overview

*Hourly interval load data*
- Random sample of 342 residential customers in Nevada without PV, under flat rates
- Data collected under DOE’s Smart Grid Investment Grant) over 2012-2014

*Modeled hourly solar PV production*
- Developed with NREL’s System Advisor Model
- Based on weather data for the same location and timeframe as the load data

*Grid exports calculated on hourly basis*
- Would be greater if based on shorter intervals

Intended to illustrate:
- Significance of grid exports
- Diversity across customers
- Impact of measures to reduce exports
- Temporal profile and implications for capacity value
Grid Exports Under a “Typical” System Design
South-facing systems sized to generate 75% of each customer’s annual consumption

- Temporal profile of exports is similar to gross PV generation, though shifted slightly leftward
- ~50% of PV generation exported, on average

- Some diversity in export percentage across customers, but most are in the 40-60% range
Targeting West-Facing Rooftops

- Grid export profile shifted with peak in early afternoon
- Still, ~50% generation exported, on average

- Grid export quantity reduced slightly for some customers, but most are still in the range of 40-60% of total PV generation
Installing Smaller Systems
Systems sized to generate 50% of annual customer load

- Lower peak but similar temporal profile as larger systems

- On average, 40% of PV generation exported; most customers in the range of 30-50%
Adding Storage to PV

13-kWh / 5-kW battery storage, with flat retail rates and grid export rates

- PV exports reduced to ~20% of total PV generation, on average
- Temporal profile shifted rightward, based on storage charging protocol under flat rates
- Exports range from 0-30% most customers (storage size is fixed, but PV size varies with load)
- Customers could install larger batteries and further reduce/eliminate exports, albeit with diminishing economic returns
Load Shifting to Reduce Grid Exports

**Literature review**

- Controllable loads for reducing PV grid exports: A/C, DHW (resistance or heat pump), appliances (e.g., dryers), pool pumps, EVs, etc.

- RMI case study of Hawaii “zero-export” tariff:
  - Low-cost A/C and DHW load-shifting measures reduce grid exports from 47% to 29% of annual PV generation
  - Additional cost-effective load shifting via controllable electric dryer (more expensive), EV, and batteries

- NREL “Solar Plus” study: A/C and DHW load-shifting almost always cost effective for managing exports

- Numerous academic studies on optimized building control with PV, mostly in European context
  - A number of such studies estimated 2-15% of PV generation could be shifted from export to self-consumption (Luthander et al. 2015), though larger shifts possible with TES (e.g., Salpakari & Lund 2016)

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**Based on RMI analysis of demand flexibility potential for Hawaii PV customer with 10 kW PV system (generation = 80% of annual load)**

- No Load Shifting: 47% PV Generation Exported, 11% PV Generation Shifted
- AC: 47% Exported, 11% Shifted
- DHW: 47% Exported, 11% Shifted
- Dryer: 47% Exported, 4% Shifted
- EV: 47% Exported, 4% Shifted
- Battery: 47% Exported, 4% Shifted

Managing Grid Exports: Summary Points

- A typical residential PV system exports ~40-60% of annual generation
  - Based on hourly netting; higher export percentage if instantaneous or 15-min netting
  - Grid export tariffs only address issues associated with this portion of PV generation

- PV exports have a similar temporal profile to gross PV generation
  - By extension, unmanaged grid exports have similar per-kWh value as gross PV generation

- Options for meaningfully managing grid exports are limited
  - Orienting panels westward has a modest impact on temporal profile; likely provides only marginal value to the customer and utility
  - Reducing system size reduces exports, but not proportionally; systems would need to be extremely small to substantially reduce annual exports
  - Load shifting options for many customers may be limited to A/C; more-significant shifting likely requires electrified water/space heating or EVs
  - Battery storage will generally be the only feasible option for most customers to significantly reduce exports
Outline

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Recent rate reforms for NEM customers have prompted rapid growth of solar + storage in several states

**Hawaii** *(grid export credit rates or prohibition on exports)*

**Salt River Project** *(demand charges for PV customers)*

**California** *(TOU rates required for solar PV customers)*

**Utah** *(for comparison)*

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**Percentage of Residential PV Installations with Battery Storage**

**Based on data from Utah Office of Energy Resources, for systems receiving the state tax credit. Data on battery storage highly incomplete prior to 2017.**
Among systems installed through CA’s SGIP in 2018:

- Median reported price of $833/kWh
- But fairly wide spread, with most systems ranging from $500-1,250/kWh
- Lower end of that spread likely represents under-reporting of total costs

Residential battery storage market is still in early stages of development and prices projected to decline rapidly

- E.g., WoodMac and Lazard both project 8% per year decline, for Li-ion battery packs

Source: California’s Self-Generation Incentive Program (SGIP)
Storage Utilization Rates for Managing Grid Exports

- Storage utilization rate (aka duty cycle) refers to the average depth of daily discharge
- A key driver for storage economics when used to arbitrage between grid export rates and retail rates
- Under grid export rates, constrained by the amount of exports
  - In turn, a function of PV system size and coincidence with customer load (see figure)
  - For typical PV system sizing, storage utilization rates might be expected to range from 50-90%

**Example:** Utilization rates for a 13-kWh/5-kW battery storage system under a grid export tariff

- Derived from sample of hourly interval load data

![Box plot of storage utilization rates](image-url)
Customer Economics of Storage for Managing Exports

Would it be economic for a customer to install storage, solely to manage grid exports?

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<th>Bookend 1</th>
<th>Bookend 2</th>
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<tbody>
<tr>
<td>Delta between average retail and grid export rates</td>
<td>$0.05/kWh</td>
<td>$0.15/kWh</td>
</tr>
<tr>
<td>Battery storage up-front cost (pre-ITC)</td>
<td>$1250/kWh</td>
<td>$500/kWh</td>
</tr>
<tr>
<td>Storage utilization rate</td>
<td>50%</td>
<td>90%</td>
</tr>
<tr>
<td><strong>Payback period (with ITC)</strong></td>
<td><strong>137 years</strong></td>
<td><strong>9 years</strong></td>
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**Bottom line:** Under highly favorable conditions, battery storage could be a (marginally) economical customer investment, just on the basis of managing grid exports.

But how well do these customer-economics align with the value to the utility system?
Rate design dictates how customers operate storage

Comparison of storage control strategies

**Charging strategy**
- Grid Export Tariffs with Flat Rates: Charge as soon as possible each day, once PV begins exporting
- Hourly Time-Varying Rates: Concentrate charging during low-cost periods

**Discharging strategy**
- Grid Export Tariffs with Flat Rates: Delay as long as possible, to preserve charge in case of outage
- Hourly Time-Varying Rates: Concentrate discharge during system or local peak demand hours
...which in turn determines its value to the utility system

Grid Export Tariffs with Flat Rates

Hourly Time-Varying Rates

Storage Dispatch on the System Peak Day

Capacity credit ≈ 0%
- Relatively little PV exports on peak load days
- No price signal for when to discharge

Capacity credit = 20-100%
- Range reflects different calculation methods
- Constrained by energy-limited nature of battery storage
The value of energy storage under a grid export tariff with flat rates vs. an idealized time-varying rate

**Considering just capacity and energy value to the bulk power system…**

- Battery storage dispatch against grid export tariffs with a flat rate provides effectively **no value** (or slightly negative value) to the utility system.

- In contrast, dispatch against hourly time-varying rates would yield energy and capacity savings of **$350-750/year** for a 5-kW/13-kWh battery storage system, depending on how capacity credit is determined.

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**Battery Storage Capacity & Energy Value**

**Illustrative comparison under two dispatch strategies**

Notes: Capacity credit under each dispatch scenario based on NV Energy system hourly loads for 2013. Capacity value then estimated based on an assumed long-run marginal cost of capacity equal to $100 per kW of utility peak demand. Energy value calculated using 2013 CAISO real-time hourly market prices for the SUMMIT_ASR-APND hub, located in Southern Nevada. For the grid export tariff, the bars represent median values, and the error bands represent the 20th and 80th percentile values, across the 342 residential customer load profiles in our sample.
Customer Economics of Storage if Compensated Directly for Capacity and Energy Value

- **Capacity value ($/kW-storage)**: $20-100/kW-yr
- **Energy value ($/kWh-storage)**: $19/kWh-yr
- **Storage system up-front cost ($/kWh-storage)**: $500-1250/kWh

**Customer payback period (with ITC)**: 6-33 years

- Could be an economic customer investment, under favorable conditions
- Other potential sources of system value (e.g., local voltage regulation and ancillary services) could further bolster these returns if communicated via rates or otherwise
- Ability to ride through customer outages may provide some additional private value

*Per the methods, data sources, and assumptions described on the previous slide*
Battery Storage for Managing Grid Exports: Summary

- Grid export tariffs can incentivize customers to install storage as a means of managing grid exports (if the price delta is high enough)
  - As evident in several jurisdictions that have already adopted grid export tariffs
- But using storage to arbitrage between retail rates and grid export rates does not necessarily provide commensurate value to the utility or ratepayers
  - Charging and discharging will often occur at times that provides only limited value to the utility system
  - Moving PV exports back behind-the-meter may re-ignite issues related to embedded-cost recovery (defeating one purpose of grid export tariffs)
- BTM storage can provide significant value to the utility system
  - But requires price signals that are more closely coupled to utility cost structure
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Acknowledgements
  This work was funded by the U.S. Department of Energy Office of Electricity, under Contract No. DE-AC02-05CH11231.
Background: *Impacts of roof-space constraints on non-residential PV system sizing*

- Roof-space constraints often limit roof-mounted PV to <25% of non-residential annual energy needs.
- Grid exports may therefore be negligible for many non-residential systems.
- Some important exceptions:
  - Warehouses
  - Schools (seasonally)
  - Ground-mounted and shade structures
Storage arbitrage value in wholesale energy markets

- RTP most common among industrial customers though overall number of customers small compared to TOU (Nezamoddini and Wang 2017)
- RTP arbitrage value has relatively low range and variability across years and markets
  - Typically $6-$14 per kWh of storage per year, though some nodes experience higher price volatility
- Reflects fairly limited differential between average peak and off-peak prices
- Greater hourly variability and arbitrage value possible if:
  - Retail RTP also reflects temporal variability in marginal transmission and distribution costs
  - Growing PV penetration leads to greater price volatility

**Annual value of bill savings from RTP arbitrage**

*Based on historical day-head hourly prices*

Notes: Based on prices from 100 randomly selected price nodes for each ISO from 2009 or latest market redesign (whichever is later) through August 2018. Storage assumed to be able to charge and discharge fully in the two lowest and highest priced hours of each day, respectively. Box plots represent 5th, 25th, 50th, 75th, and 95th percentiles.