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Assessing the New Home Market Opportunity: Case Study and Cost Modeling for Solar and Storage in 2030

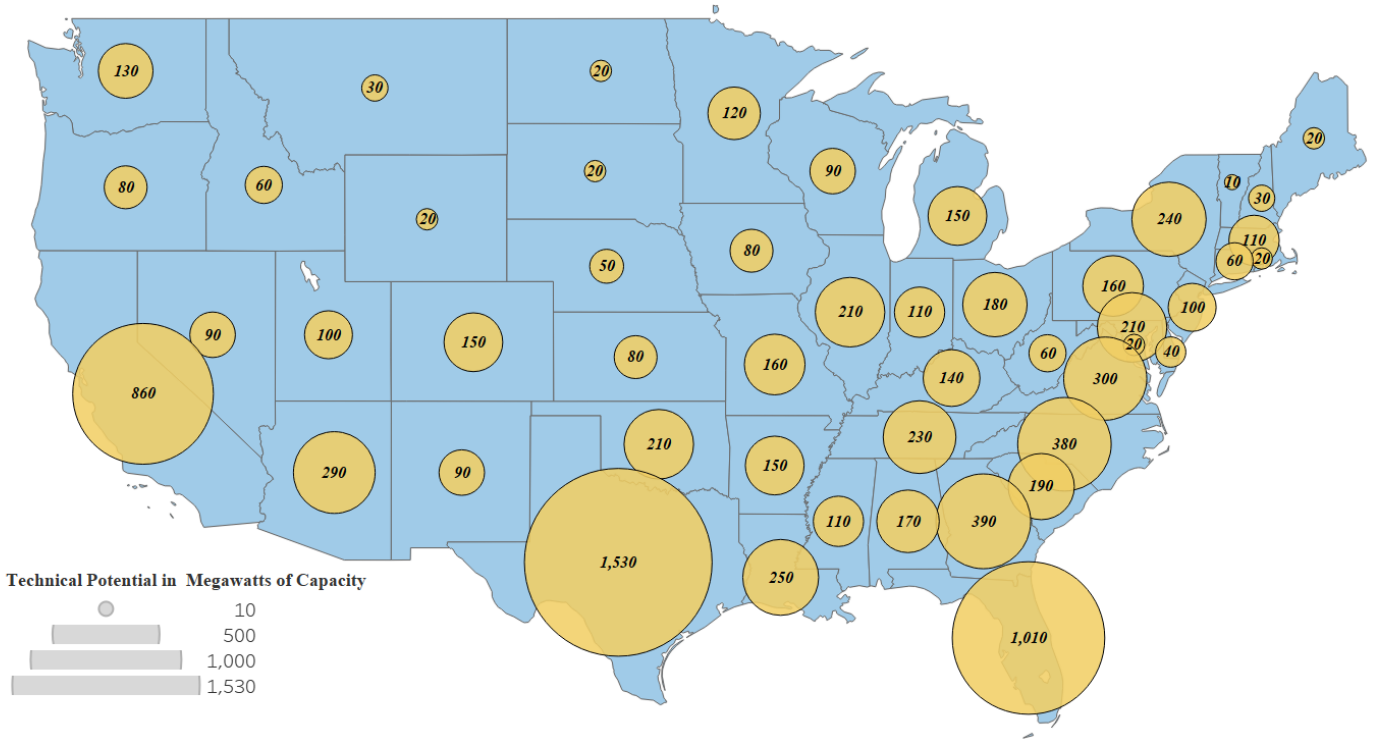
Jeffrey J. Cook, Kaifeng Xu, Vignesh Ramasamy, Minahil Qasim, and Matt Miccioli

Introduction

The U.S. Residential Solar and Storage Market

- In 2020, the United States had a cumulative 19 gigawatts (GWdc) of residential solar photovoltaic (PV) capacity. A growing percentage of these solar installations are paired with battery storage, up from 0.1% in 2015 to 8.1% in 2020.
- Some states are considering or have already adopted policy mandates to require solar and storage systems.
- The cost of installing residential solar and battery storage projects remains a barrier to widespread adoption nationwide. For example, the cost of a typical residential retrofit solar and storage system ranges from $26,153 to $37,909, which is 38% to 100% higher than a standalone PV system.

Annual average technical potential for residential rooftop PV at time of new construction projected between 2017 and 2030



Study Goals

- Analyze the current solar and storage installation process in new home construction
- Identify potential barriers and opportunities for scaling this model nationwide
- Learn how to create pathways to reduce installation costs and expand solar and storage market penetration in this sector

NREL estimates that 0.96 million new homes are expected to be constructed each year between 2017 and 2030.

New Construction Solar and Storage Barriers

- The cost of solar and storage is likely to be a barrier to widespread adoption.
  - Current analyses typically evaluate residential solar and storage costs separately from each other.
- In 2020, about eight months was the average length of time needed to construct a new single-family residential home in the U.S., from authorization to completion.
  - It is unclear what, if any, impacts solar and storage systems have on new home construction processes.
  - Any construction delays caused by solar and storage projects, coupled with higher home costs, may make homebuilders reluctant to offer these options to prospective customers.

Case Study

Study Overview

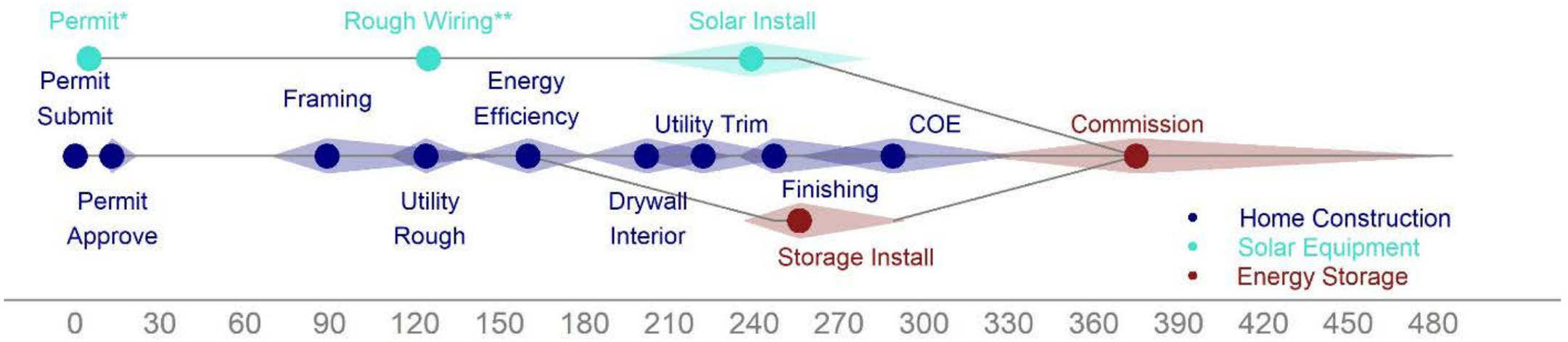
- NREL conducted a case study of Mandalay Homes' new solar and storage community in Arizona.
- To model current and 2030 solar and storage costs, the authors used an NREL-created, bottom-up cost model*.
- This modeling was further informed by 12 organizations that included new homebuilders, solar and storage contractors, equipment providers, and other subject matter experts.

*2020 was used as the baseline for this project, given it was the most recent year for which cost data was available at the time of analysis.

About Mandalay Homes

- The goal of this analysis is to shed light on how solar and storage can be incorporated into the new home construction process and what lessons can be gathered for similar projects in the future.
- Builder Mandalay Homes partnered with German battery maker sonnen to bring rooftop photovoltaic solar panels and battery storage to 3,300 new homes in Arizona. The homes will generate 80% of the power they need on an annual basis.
- Since 2012, Mandalay has been exclusively building homes that meet the DOE standard, and has certified more homes than any other builder in the country. The concept of the development in Prescott, Arizona has roots in the Department of Energy's Zero Energy Ready Home Program.

Mandalay Homes Cumulative Duration (Days) Based on Stage Median Durations



NREL collected construction data from 150 Mandalay homes and identified the following:

- Solar is frequently installed during the trim stage, when all other roof features and painting are complete.
- Storage follows thereafter, as landscaping activities are finalized.
- Systems are typically commissioned after the homeowner has entered the house and has set up their utility service.

*Solar and storage permitting can occur in parallel or can be combined with the new home permit. In this case, the permits were submitted separately, and data was not available on permit submission times.

**Rough wiring of the system occurs during the utility rough stage of the new construction process. NREL was not able to collect data on the duration of this step, but multiple houses can be rough wired in one day (if ready).

Solar and Storage Impacts and Lessons Learned

- Incorporating solar and storage into new home construction adds a layer of complexity to the building process.
- Permitting- and inspection-related issues were commonly cited by stakeholders. These issues stemmed from variation in the enforcement of codes by local governments and local officials' unfamiliarity with the storage technology being employed.
- Although incorporating solar and storage into the new construction process did not delay construction, it still required additional communication and coordination between trades.
- Although these coordination issues increase as construction scales, so too do economies of scale. Pathways to further cost reductions, via economies of scale or otherwise, may be essential going forward.

Modeled New Home Solar and Storage Costs

Methodology

- NREL used a quantitative model to estimate 2020 and 2030 installation costs for solar and storage at the time of new construction.
    - Stakeholder cost suggestion inputs
    - NREL bottom-up cost model
- NREL developed a new Q1 2020 cost benchmark for a new-construction, residential solar and storage installation based on the published 2020 retrofit system benchmark.
- Three cost-reduction scenarios (Conservative, Moderate, Advanced) were generated from the literature and stakeholder feedback. These three scenarios attempt to showcase a variety of hardware and soft cost-reduction opportunities through 2030.

Cost – Benchmark

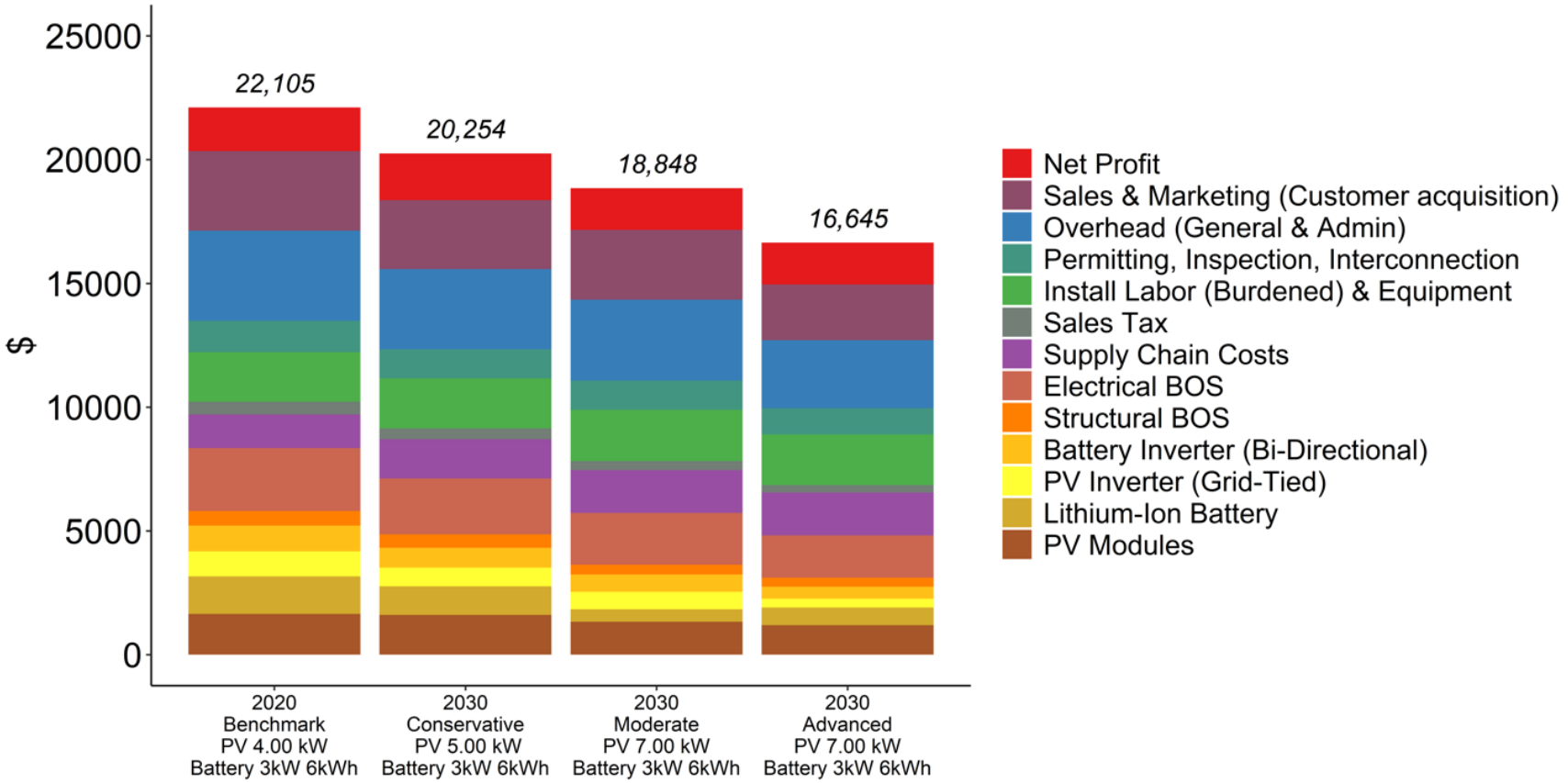
Category	2020 Retrofit Case	2020 New Construction Benchmark	Assumptions, from Retrofit to new Construction
PV System Size	7 kW	4 kW	Size changed due to stakeholder inputs
Battery System Size	3 kW/6 kWh storage	3 kW/6 kWh storage	No changes
PV-Module Efficiency	19.5%	19.5 %	No changes
PV Inverter Price	0.25/Wdc	0.25/Wdc	No changes
PV Module Price	$ 0.41/Wdc	$ 0.41/Wdc	No changes
Lithium-ion Battery	$253/kWh	$253/kWh	No changes
Battery-based Inverter Cost	$174/kWh	$174/kWh	No changes
Structural BOS	$589	$595	Slight change due to revised model construction and inflation
Electrical BOS	$2,755	$2,538	Change due to revised model construction and inflation, and revised PV size
Supply Chain	$2,025	$1,359	
Sales Tax	$704	$514	No change in 5% tax rate, cost declines given total install cost declined
Install Labor (Burdened) & Equipment	$2,252	$ 1,996	Slight change due to revised model construction and inflation, and revised PV size
PII	$1,668	$1,273	PII reduced by 25% (Feldman et al., 2021)
Overhead (General and Administrative)	$ 3,584	$3,637	Slight change due to revised model construction and inflation
Sales and marketing (Customer Acquisition)	$ 5,496	$3,221	Sales and marketing costs reduced by 25% (Feldman et al., 2021)
Profit (%)	$2,164	$1,758	No change in profit margin %, cost change due to revised PV size
Total	$ 28,371	$ 22,105	Reduced by 22%

Note: Both AC- and DC-coupled systems were modeled, and focusing AC-coupled system costs

Cost – By Scenarios

Category	Benchmark	Conservative	Moderate	Advanced	Key Assumptions
PV System Size	4 kW	5 kW	7 kW	7 kW	Size increase in the future
Battery System Size	3 kW/6 kWh	3 kW/6 kWh	3 kW/6 kWh	3 kW/6 kWh	Size remains the same, given electrification and efficiency gains balance each other
PV-Module Efficiency	19.5 %	21.5%	22.5%	25%	Efficiency gains are expected, but improvement rates are uncertain
PV Inverter Price	0.25/Wdc	$0.15/Wdc	$ 0.10/Wdc	$0.05/Wdc	Prices are expected to decline, but decrease rates are uncertain
PV Module Price	$ 0.41/Wdc	$ 0.32/Wdc	$0.19/Wdc	$ 0.17/Wdc	Prices are expected to decline, but decrease rates are uncertain
Lithium-ion Battery	$253/kWh	$193/kWh	$83/kWh	$119/kWh	Prices are expected to decline, but decrease rates are uncertain
Battery-based inverter cost	$174/kWh	$ 133/kWh	$117/kWh	$82/kWh	Prices are expected to decline, but decrease rates are uncertain
Structural BOS	$595	$540	$397	$357	Costs may decline as fewer components are needed to be installed, but decrease rates are uncertain
Electrical BOS	$2,538	$ 2,262	$ 2,091	$ 1,712	Costs may decline as fewer components are needed to be installed, but decrease rates are uncertain
Supply Chain	$1,359	$ 1,169	$ 1,735	$ 1,735	Supply chain costs are variable, but delivery of fewer parts and bulk purchasing may reduce costs
Sales Tax (%)	$514	$ 441	$ 361	$ 299	Taxes remain at 5% fixed rates. Costs decline based on overall project costs declining
Install Labor (Burdened) & Equipment	$ 1,996	$ 2,017	$ 2,067	$ 2,047	Labor costs remain largely flat, as wages may increase even if labor hours decline
PII	$1,273	$ 1,179	$ 1,185	$ 1,061	Streamlined PII processes and requirements may result in lower costs, but application fees are expected to remain constant
Overhead (General and Administrative)	$3,637	$ 3,240	$ 3,268	$ 2,747	Overhead costs are assumed to decline as solar and storage becomes a more standard product and business structures evolve at varying rates
Sales and marketing (Customer Acquisition)	$3,221	$ 2,789	$ 2,818	$ 2,251	Sales and marketing costs are expected to decline as solar and storage is offered more frequently or as a standard product in new homes
Profit (%)	$1,758	$ 1,186	$ 1,688	$ 1,688	Though profit margins increase as a percentage of overall costs, they decline slightly in the moderate and advanced cases due to expected competition and economies of scale
Total	$ 22,105	$19,138	$18,848	$16,645	

Comparison of Current and 2030 Residential Solar and AC-coupled Storage Costs



If these cost-reduction opportunities are maximized, residential new construction costs could decline 8%–25% by 2030, depending on the modeled scenario.

Cost Reduction Percentage Contribution by Category

Segment	2030 Conservative	2030 Moderate	2030 Advanced
PV and Battery Hardware	48.52%	60.67%	45.16%
Sales and Marketing (Customer Acquisition)	23.32%	12.36%	17.76%
Overhead (General and Admin)	21.41%	11.33%	16.30%
Electrical BOS	14.89%	13.73%	15.12%
Structural BOS	2.99%	6.08%	4.35%
Sales Tax	3.97%	4.71%	3.95%
PII	5.10%	2.70%	3.88%
Net Profit	-6.91%	2.14%	1.28%
Installation Labor (Burdened) and Equipment	-1.10%	-2.19%	-0.93%
Supply Chain Costs	-12.19%	-11.53%	-6.88%
Total Reduction, $ and % Compared With Benchmark	$1,851 (8.4%)	$3,257 (14.7%)	$5,460 (24.7%)

PV and battery materials, such as the module, battery pack, and inverter segments, contributed between 45% and 61% of the total estimated cost reduction, depending on the scenario.

Two soft cost categories, customer acquisition and overhead, account for ~11%–23% of the cost reduction.

Electrical BOS costs account for 14%–15% of the cost reduction.

Cost Savings Opportunities and Barriers - Hardware

- Though modules and inverters have already seen significant cost reductions, interviewees confirmed that additional savings could result from increased manufacturing automation and continued technology innovations, especially for the battery.
- Interviewees further noted that there are a variety of factors that could result in hardware costs remaining the same or declining at a slower rate in the future (e.g., PV module prices have risen 6% in Q1 2021 due to the increasing shipping costs of sourcing materials).
- The development, commercialization, and regulatory approval of these technologies can take time, thereby reducing the potential impact these innovations could have by 2030.

Cost Savings Opportunities and Barriers – Customer Acquisition

- Customer acquisition costs are lower in the context of new construction than retrofits. These cost savings could accelerate in the future, especially as solar and storage at the time of new construction gains market share.
- If homebuilders take a similar approach to that of Mandalay, then solar and storage contractors would have significantly lower customer acquisition costs.
- Potential barrier: With housing costs increasing, homebuilders and homeowners may be hesitant to add this higher cost product, making customer acquisition more challenging.

Cost Savings Opportunities and Barriers - Overhead

- The overhead category incorporates a wide variety of costs, including office space, management, and accounting, among others. This is also a category in which excess or otherwise hidden costs elsewhere might be captured.
- Interviewees confirmed that economies of scale and the ability to distribute overhead costs over a wider pool of projects can further result in reduced overhead costs on a per-project basis.
- Potential barrier: Local governments and utilities continue to have widely different PII requirements for solar, even though solar has been rapidly increasing its market share for more than a decade.
- Potential barrier: Contractors seeking to expand their business results in more overhead costs that need to be spread across an ever-growing pool of projects.

Cost Savings Opportunities and Barriers - Labor

- Labor costs could go down if fewer modules and other equipment need to be installed on site. This could happen as a result of technology improvements and/or off-site automation.
- Potential barrier: Some interviewees pointed out that labor rates only increase over time, not decrease. Moreover, it may be difficult to find and/or train the workforce needed to complete solar and storage installations. This may require increases in labor rates to carry out the same work.

Market Opportunities Beyond Cost Savings

1. Financing
2. Rate Design
3. Resilience Programs and Policies
4. Solar and Storage Deployment Mandates
5. DER Aggregation Programs

Conclusion

Conclusion

- Three key considerations for homebuilders deploying solar and storage:
    1. Educating local permitting, inspection, and in some cases utility officials on solar and storage products, designs, and code compliant building practices may be required.
    2. Incorporating solar and storage systems into the homebuilding process can add complexity and related coordination challenges, but this does not need to result in home construction delays.
    3. Deploying solar and storage at the time of new construction has significant economies of scale, which offer potential cost savings opportunities and can thus improve the value proposition of the systems.
- If future contractors can maximize the cost reduction opportunities of solar and storage, costs may decline 13–25% from the 2020 baseline by 2030.
- Cost reductions are not the only pathway to increase solar and storage deployment at the time of new construction.

For more information, download the full technical report: Jeffrey J. Cook, Kaifeng Xu, Vignesh Ramasamy, Minahil Qasim, and Matt Miccioli, 2022. *Assessing the New Home Market Opportunity: Case Study and Cost Modeling for Solar and Storage in 2030*.
Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-82511.
https://www.nrel.gov/docs/fy22osti/82511.pdf.

For questions, contact Jeff.Cook@nrel.gov.

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