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Tuesday, February 15, 2022

The Honorable Delores Kelley
Chair, Senate Finance Committee
Miller Senate Office Building - 3 East
Annapolis, Maryland 21401

SB 418 – Energy Generation, Transmission, and Storage Projects – Required Community Benefit Agreement and Labor Standards

Position – Favorable

Thank you Chair Kelley and members of the Senate Finance Committee for the opportunity to submit written testimony in support of SB 418.

My name is Victoria Leonard, Political and Legislative Director for the Baltimore-Washington Laborers' District Council (BWLDC), an affiliate of the Laborers' International Union of North America, or LiUNA for short. The BWLDC represents more than 7,500 members across Maryland, Virginia, and the District of Columbia. Our members are proudly employed on many infrastructure construction projects across the region.

LiUNA supports SB 418 and its establishment of labor standards for energy generation projects. As the state of Maryland shifts to a green economy and away from fossil fuels, it is essential that the jobs created by the transition are quality jobs with benefits. Labor standards on energy generation projects help do just that.

For example, the labor standards included in SB 418 are applying prevailing wage to the construction of energy generation projects that need CPCNs and requiring best efforts to enter into agreements with affected communities regarding jobs for local residents and businesses, training, and safety protocols.

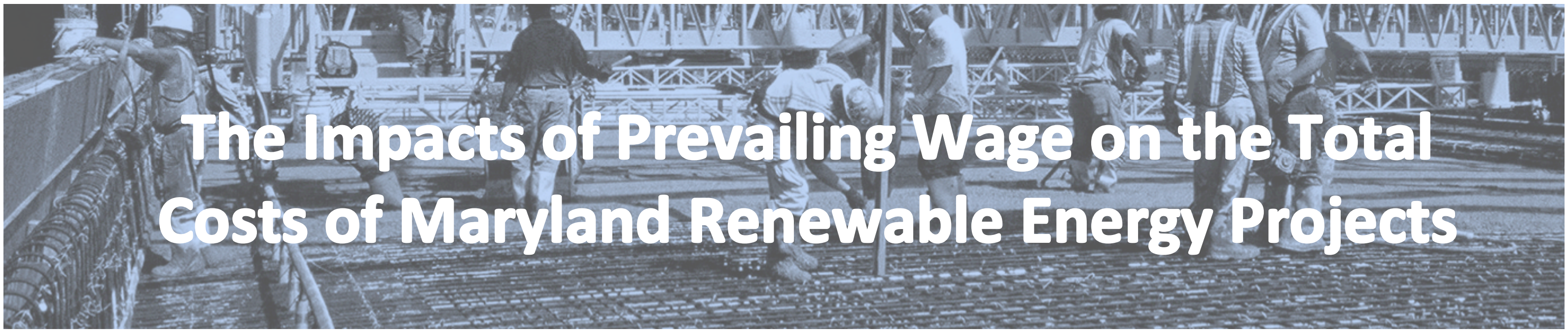
The prevailing wage standards are especially important because energy developers and construction contractors sometimes engage in business practices that do not promote quality jobs for local residents or opportunities for local businesses. These practices include: use of a traveling workforce, effectively boxing out opportunities for local employment; reliance on temporary staffing agencies like PeopleReady, whose workers in several states repaid wages so low they receive federal food assistance and Medicaid benefits; and misclassification of workers as 1099 independent contractors to avoid payroll taxes.

Moreover, extending the state's prevailing wage to energy generation aligns with the General Assembly's goal to create quality infrastructure jobs. Economic analysis of the legislation reveals that labor costs are only 5% of the total cost of energy development projects. Those costs are capitalized over the useful life of the project. Consequently, this legislation will have no impact on retail energy rates. Attached to my testimony is a cost analysis prepared by Pinnacle Economics supporting the de minimis impact of prevailing wage on the costs of renewable energy projects, as well as a brief summary of that study.

Finally, if SB 418 becomes law, Maryland would be joining other states like Illinois, Connecticut, New Jersey, Oregon, Washington, Minnesota, and New York that have already passed laws to establish labor standards for energy projects.

LiUNA urges the committee to vote favorably on SB 418.

The Impacts of Prevailing Wage on the Total Costs of Maryland Renewable Energy Projects



BACKGROUND

Other than offshore wind, Maryland's renewable energy projects are not subject to prevailing wages or other types of labor standards. In contrast, many other states, including New York, Illinois, New Jersey, and Connecticut, have enacted comprehensive labor standards for renewable energy projects. It is time for Maryland to do the same. Toward that goal, the Baltimore-DC Building Trades retained Pinnacle Economics, Inc. to evaluate how a prevailing wage requirement for renewable energy projects in Maryland would affect total project costs. Pinnacle's analysis focused on: 1) utility-scale and commercial solar, 2) land-based wind, 3) geothermal, and 4) energy storage (batteries).

PREVAILING WAGE IMPACT

- **Installation labor costs generally represent a small portion – typically 10 percent or less – of total renewable energy project costs** (see Figure 1, left column)**.** Equipment costs, including electrical and structural balance of system costs, primarily drive total project costs.
- **Consequently, the impact of extending prevailing wage to renewable energy projects is de minimis.** For example, a 30 percent increase in labor costs increases total project costs roughly between 2 and 3 percent, depending on the type and size of the system (see Figure 1, far right column and Figure 2).

FIGURE 1

Installation Labor Costs and Changes in Total Project Costs
Attributed to Hypothetical Changes in Install Labor Costs, by Type of Renewable Energy (2019)

	Install Labor Costs	Percent % in Project Costs Associated with the Following % Changes in Labor Costs			
Resource / Technology	as % of Total Capital Costs	1%	10%	20%	30%
Solar: Utility-Scale Fixed-Tilt (Low - 5 MW)	9.68%	0.10%	0.97%	1.94%	2.90%
Solar: Utility-Scale Fixed-Tilt (High - 100 MW)	10.64%	0.11%	1.06%	2.13%	3.19%
Solar: Utility-Scale One-Axis (Low - 5 MW)	9.70%	0.10%	0.97%	1.94%	2.91%
Solar: Utility-Scale One-Axis Solar (High - 100 MW)	10.89%	0.11%	1.09%	2.18%	3.27%
Solar: Commercial Rooftop (2 MW)	6.96%	0.07%	0.70%	1.39%	2.09%
Solar: Commercial Ground (2MW)	9.15%	0.09%	0.92%	1.83%	2.75%
Wind: Land-Based (2.6 MW Turbines)	6.21%	0.06%	0.62%	1.24%	1.86%
Wind: Fixed-Bottom Offshore (6.1 MW Turbines)	9.34%	0.09%	0.93%	1.87%	2.80%
Wind: Floating Offshore (6.1 MW Turbines)	10.32%	0.10%	1.03%	2.06%	3.09%
Battery Storage: Utility-Scale 60 MW Lithium-ion	5.67%	0.06%	0.57%	1.13%	1.70%
Geothermal: 50 MW Flash Plant (bottom exhaust)	8.03%	NA	NA	NA	NA
Geothermal: 40 MW Flash Plant (top exhaust)	7.58%	NA	NA	NA	NA
Geothermal: 50 MW Binary Plant	3.02%	NA	NA	NA	NA

Note: Changes in total project costs for geothermal projects not estimated because install labor costs are based on union workers receiving prevailing wages and benefits. Offshore wind energy included for context.
Sources: Pinnacle Economics using detailed NREL and EPRI project cost data.

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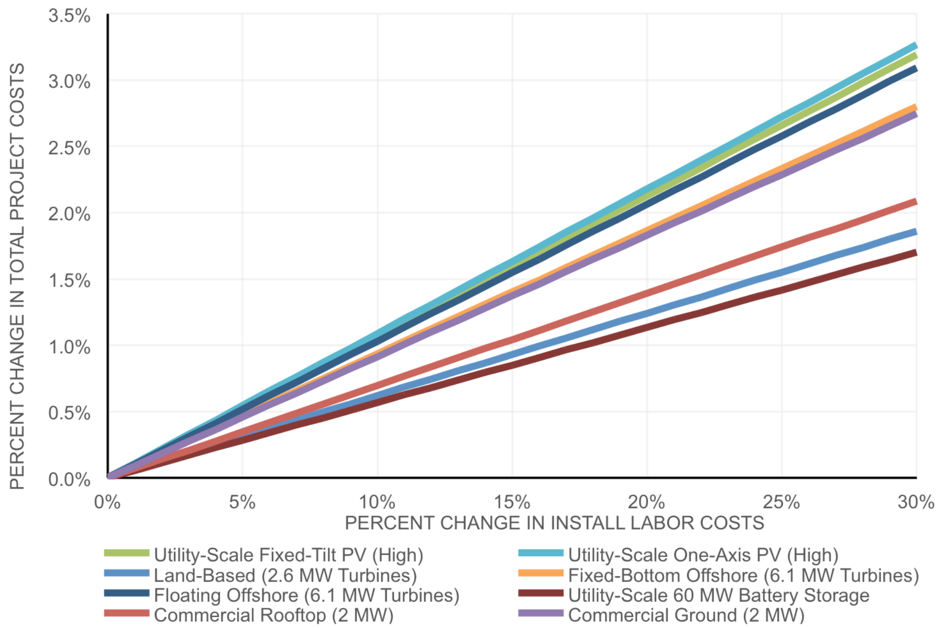
- **A 30 percent prevailing wage premium is likely a conservative estimate because:**
  - The analysis does not include increases in worker productivity linked to a higher prevailing wage, such as lower worker turnover, greater access to apprenticeship training programs, and improved workplace safety.
  - Total installation costs have fallen dramatically over the last ten years, and are forecast to continue to decline over the next 30 years.
  - Installation labor costs can include equipment, as well as occupations not directly affected by prevailing wages.
  - Economies of scale for some technologies reduce average labor costs more than average total costs, thus reducing installation labor's percentage of total costs.
  - NREL's benchmark costs are based on national averages, where California is over-weighted and where that state's high cost of labor biases labor costs upward (labor costs in Maryland on commercial solar, for example, are 16 percent lower than the national average).

FIGURE 2

Sensitivity of Total Project Costs to Changes in Install Labor Costs, by Type of Renewable Energy Project



Sources: Pinnacle Economics using detailed NREL and EPRI project cost data.

The Impacts of Prevailing Wages on the Total Costs of Maryland Renewable Energy Projects

INTRODUCTION[1]

Maryland first enacted a prevailing wage law in 1945 for road construction projects in three counties, and over the years the General Assembly has expanded the law to include a broader range of infrastructure projects. Most recently, in 2019, Maryland extended its prevailing wage law to offshore wind projects and, in 2021, to investor-owned underground gas and electric utility construction.

As Maryland shifts away from traditional fossil fuels, it is essential that the transition to renewable energy is just and equitable. However, other than offshore wind, Maryland's renewable energy projects are not subject to prevailing wages or other types of labor standards. In contrast, many other states, including New York, Illinois, New Jersey, and Connecticut, have enacted comprehensive labor standards on renewable energy projects. It is time for Maryland to do the same.

Toward that goal, the Baltimore-DC Building Trades ("BDCBT") retained Pinnacle Economics, Inc., ("Pinnacle") to evaluate how a prevailing wage requirement for construction trades working on renewable energy projects in Maryland would affect total project costs. This report includes the following types of renewable energy projects: 1) utility-scale and commercial solar, 2) land-based wind, 3) geothermal, and 4) energy storage (batteries). In order to provide maximum context and to avoid any confirmation bias, this analysis includes a broad array of renewable energy technologies, regardless of whether they will be covered by labor standards or, in the case of offshore wind power, already are included or covered by labor standards.

EXECUTIVE SUMMARY

The additional costs to ratepayers of extending Maryland's prevailing wage law to non-residential solar, land-based wind, geothermal, and energy storage projects that are 2 MW or greater is negligible.

This is due, primarily, to the cost structure of renewable energy projects, where total project costs are most heavily influenced by equipment costs, including electrical and structural balance of system ("BOS") costs,[2] and less influenced by install labor costs which generally represent 10 percent or less of total project costs. As shown in the first section (shaded in dark gray) of Table ES1, for example, install labor costs represent 3.02 percent of total project costs for a 50 MW geothermal binary plant and 10.89 percent of total project costs for a utility-scale solar (photovoltaic or "PV") facility using one-axis solar technology. These cost estimates are derived

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[1] This analysis was conducted by Alec Josephson, of Pinnacle Economics. He would like to thank Steve Courtien of the Baltimore-DC Building Trades and Victoria Leonard of the Baltimore Washington Laborer's District Council, LiUNA, for their project oversight and review. This introduction was prepared by BDCBT and LiUNA staff.

[2] For example, for utility-based solar, modules, inverters, and BOS account for between 55-65 percent of total project costs, depending on the type of solar technology. For land-based wind, equipment costs (rotor, nacelle, and tower) account for 69 percent of total project costs.

using detailed, objective, industry-derived cost data from the National Renewable Energy Laboratory ("NREL") and other government or industry sources.

Table ES1: Install Labor Costs and Changes in Total Project Costs Attributed to Hypothetical Changes in Install Labor Costs, by Type of Renewable Energy (2019)

Resource / Technology	Install Labor Costs as % of Total Capital Costs	Percent % in Project Costs Associated with the Following % Changes in Labor Costs			
		1%	10%	20%	30%
Solar: Utility-Scale Fixed-Tilt (Low - 5 MW)	9.68%	0.10%	0.97%	1.94%	2.90%
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Geothermal: 50 MW Flash Plant (bottom exhaust)	8.03%	NA	NA	NA	NA
Geothermal: 40 MW Flash Plant (top exhaust)	7.58%	NA	NA	NA	NA
Geothermal: 50 MW Binary Plant	3.02%	NA	NA	NA	NA

Note: Changes in total project costs for geothermal projects not estimated because install labor costs are based on union workers receiving prevailing wages and benefits. Offshore wind energy included for context.
Sources: Pinnacle Economics using detailed NREL and EPRI project cost data.

The second section (shaded in light gray) of Table ES1 reports how changes in install labor costs affect total project costs. For example, install labor costs represent 6.21 percent of total project costs for utility-scale, land-based wind. Thus, every one percent increase in install labor costs translates into a 0.06 percent increase in total project costs. Based on a prevailing wage law that results in a hypothetical 30 percent increase[3] in construction wages, Pinnacle estimates that total project costs would increase, depending on the size of the system, between:

- 2.90 and 3.19 percent for utility-scale, fixed-tilt solar
- 2.91 and 3.27 percent for utility-scale, one-axis solar
- 2.09 percent for commercial rooftop solar
- 2.75 percent for commercial ground-mount solar
- 1.86 percent for land-based wind
- 1.70 percent for energy storage

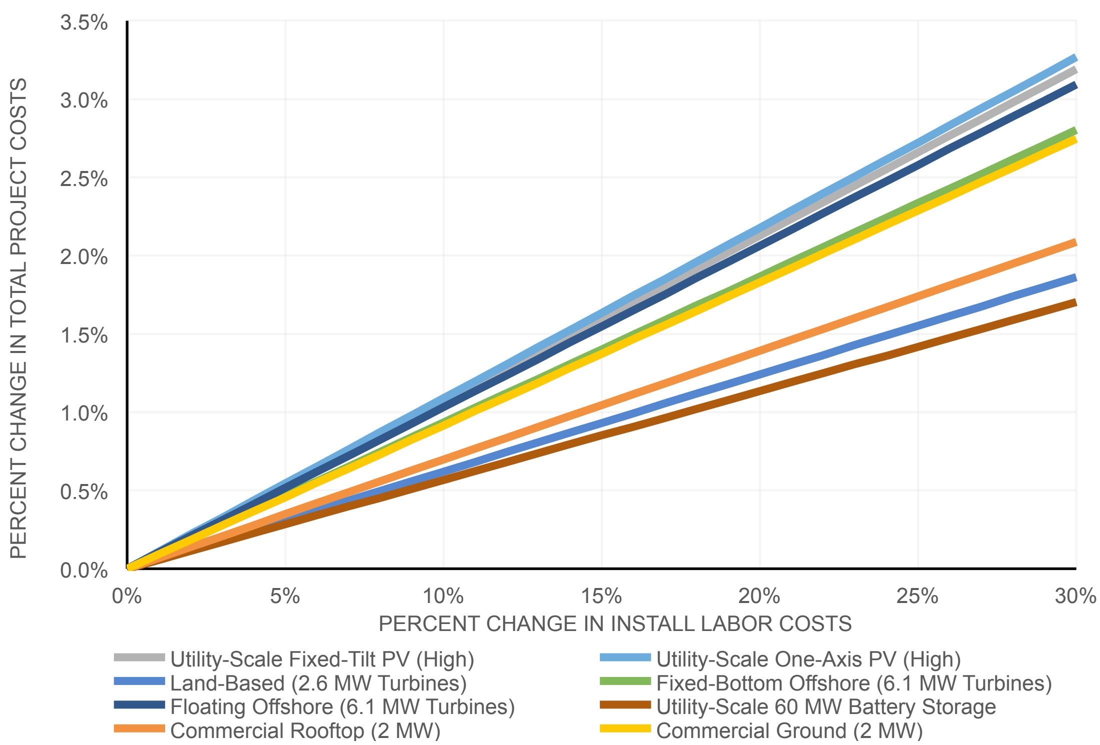
[3] A hypothetical 30 percent increase in construction wages due to prevailing wage likely is a conservative estimate: 1) a November 2020 study entitled *Potential Impacts of Prevailing Wage on Solar Costs in Illinois* found that prevailing wage could increase solar labor rates from an average of 23 to 41 percent when accounting for total compensation packages including healthcare, pension and worker training contributions (see https://drive.google.com/file/d/13ZWw7rOiIomG_mURNcmD0cw1p934FBSX/view); and 2) the Maryland General Assembly's Department of Legislative Services has found that prevailing wages tend to be higher than non-prevailing wages, but that it is reasonable to expect that the prevailing wage requirement adds at most between 2% and 5% to the cost of a public works project (see https://mgaleg.maryland.gov/2021RS/fnotes/bil_0005/sb0095.pdf).

These estimates are likely conservative given that:

1) Install labor costs can include equipment, as well as occupations that are not directly affected by prevailing wages,
2) Economies of scale for some technologies that reduce average labor costs more than average total costs, thus reducing install labor's percentage of total costs,
3) NREL's benchmark costs are based on national averages, where California is overweighted and where that state's high cost of labor biases labor costs upward (labor costs in Maryland on commercial solar, for example, are 16 percent lower than the national average), and
4) This analysis does not include increases in worker productivity that linked to a higher prevailing wage, such as: lower worker turnover, better and more prevalent apprenticeship training programs, improved workplace safety, and more.

Lastly, these *de minimus* changes in total project costs should be viewed within the context that total install costs of renewable energy have fallen dramatically over the last ten years, and that costs are forecast to continue to decline over the next 30 years. Figure ES1 shows the sensitivity of total project costs to changes in install labor costs for the renewable energy projects considered in this analysis.

Figure ES1: Sensitivity of Total Project Costs to Changes in Install Labor Costs, by Type of Renewable Energy Project



Sources: Pinnacle Economics using detailed NREL and EPRI project cost data.

DETAILED ANALYSIS AND FINDINGS

The BDCBT and its affiliates are seeking to establish labor standards, including prevailing wages, for construction trades employed on renewable energy projects in Maryland. Projects that would be subject to labor standards include renewable energy generation projects 2 MW or greater as outlined in Tier 1 and Tier 2 of Maryland's Renewable Energy Portfolio Standard ("RPS") Program,[4] as well as nuclear energy and energy storage devices.[5]

BDCBT retained Pinnacle Economics to evaluate the impacts on total project costs from prevailing wages for construction trades working on the following types of renewable energy projects: 1) commercial (2 MW) and utility-scale solar, 2) land-based wind, 3) geothermal, and 4) battery storage. The following sections use detailed cost data for these renewable energy projects to measure the sensitivity of total capital costs to higher install labor costs under prevailing wages.

1. Non-Residential Solar (Photovoltaics or "PV")

Due to improvements in solar module efficiencies, and declines across major cost components—particularly solar equipment (modules, inverters, BOS)—the installed costs of solar energy declined significantly between 2010 and 2020. As shown in Table 1, installed costs decreased 80-82 percent for utility-scale PV, 69 percent for commercial PV, and 64 percent for residential PV over this ten year period.

These trends are expected to continue, as NREL forecasts that the installed costs for utility-scale PV will decline by 65 percent between 2020 and 2050. Similarly, installed costs for commercial and residential PV are forecast to decline by 70 percent and 80 percent, respectively, over the same time period.

[4] Under Maryland's RPS Program, electricity suppliers must meet annual requirements for the installation of renewable energy generation. Tier 1 renewable energy technologies include solar (energy from photovoltaics and solar water heating systems), wind, qualifying biomass, methane from a landfill or wastewater treatment plant, geothermal, ocean, fuel cell (that produces electricity from a Tier 1 source), hydroelectric power plants less than 30 MW capacity, poultry litter-to energy, waste-to-energy, and refuse-derived fuel. Tier 2 includes hydroelectric power other than pump storage. Source: Maryland Public Service Commission, https://www.psc.state.md.us/electricity/maryland-renewable-energy-portfolio-standard-program-frequently-asked-questions/

[5] With the exception of energy storage projects subject to § 7-216 of the Code of Maryland.

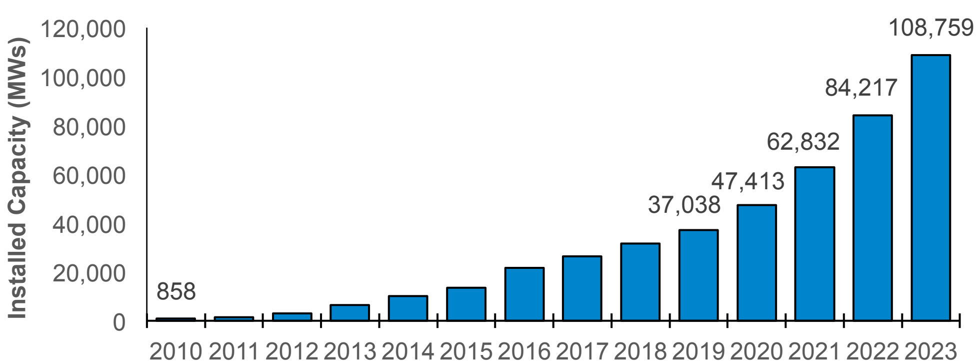
Table 1: Installed PV Costs, by Type of Project, 2010-2020 (2019 dollars per MW_{DC})

Year	Utility-Scale PV Fixed Tilt (100 MW)	Utility-Scale PV One-Axis Tracker (100 MW)	Commercial Rooftop PV (200 kW)	Residential PV (22 panel system)
2010	$4.75	$5.66	$5.57	$7.53
2011	$4.08	$4.79	$5.18	$6.62
2012	$2.77	$3.29	$3.57	$4.67
2013	$2.13	$2.50	$2.90	$4.09
2014	$1.97	$2.25	$2.89	$3.60
2015	$1.93	$2.08	$2.40	$3.36
2016	$1.53	$1.63	$2.29	$3.16
2017	$1.08	$1.16	$1.94	$2.94
2018	$1.08	$1.16	$1.88	$2.78
2019	$0.95	$1.02	$1.76	$2.77
2020	$0.94	$1.01	$1.72	$2.71

Sources: 1) Feldman, et. al., "U.S. Solar Photovoltaic System and Energy Storage Cost Benchmark: Q1 2020," National Renewable Energy Laboratory (NREL), Technical Report, NREL/TP-6A20-77324, January 2021. 2) NREL, https://www.nrel.gov/news/program/2021/documenting-a-decade-of-cost-declines-for-pv-systems.html, and 3) NREL Advanced Technology Baseline, https://atb.nrel.gov/electricity/2021/about.

As the installed costs of PV has decreased, the installed PV capacity has increased.[6] In the electric power sector—i.e., excluding small scale PV in residential, commercial, industrial, and other sectors— installed, large-scale PV capacity increased significantly between 2010 and 2020, and is expected to continue this growth over the next several years adding 21 GW of capacity in 2022 and 25 GW of capacity in 2023. (See Figure 1.)

Figure 1: Large-Scale PV Installed Capacity (MW), Electric Power Sector (2010-2023)



Source: U.S. Energy Information Administration ("EIA"), Short-term Energy Outlook, January 11, 2022, https://www.eia.gov/outlooks/steo/report/electricity.php.

[6] In economics, cost decreases will increase supply, i.e., more will be supplied at each and every price. Along a given demand curve, this increase in supply leads to an increase in quantity produced (sold, or consumed). However, renewable energy resources are also witnessing an increase in demand. All else the same, increases in supply and demand will unambiguously lead to an increase in quantity.

This analysis focuses on utility-scale and commercial PV.[7] All solar capital cost (or total project cost) assumptions are from the National Renewable Energy Laboratory's ("NREL") U.S. benchmark studies, including the most recent benchmark study for 1Q 2020.[8] NREL uses a bottom-up approach that accounts for all installation costs from the perspective of the developer/installer, i.e., costs include profits and represent the final retail price paid to the developer/installer. NREL reports detailed benchmark costs for various PV technologies and system sizes for 11 different cost categories.

1.A. Utility-Scale PV

NREL reports U.S. benchmark capital costs for utility-scale PV for fixed-tilt and one-axis tracking systems for various system sizes.

- **Fixed-tilt systems** do not change their orientation to the sun, are cheaper to install, and generally require less land. In addition, fixed-tilt systems are better at capturing diffuse radiation and are more common in the eastern U.S., where cloud cover reduces direct radiation from the sun. According to data collected by the U.S. Energy Information Administration ("EIA"), between 2010 and 2020, fixed-tilt PV systems accounted for 78 percent of the installed PV (as measured by nameplate capacity, MWs) in Maryland.[9] In addition, the average size of fix-tilt systems in Maryland is 4.0 MW, over the ten year reporting period. By comparison, fixed-tilt systems nationwide accounted for 34 percent of installed nameplate capacity, with an average system size of 5.5 MW.
- **One-axis (and dual-axis) tracking systems** are more expensive, but, because they track the movement of the sun, are better able to capture direct radiation from the sun. As a result, they are more common in the southwest region of the U.S., where cloudless days are more abundant. In Maryland, according to the EIA, between 2010 and 2020, one-axis tracking systems accounted for 22 percent of installed solar PV (as measured by nameplate capacity, MWs) with an average system size of 3.4 MWs. By comparison, one-axis tracking systems account for 65 percent of installed solar nationally and have an average system size of 19.6 MWs.

U.S. benchmark capital costs for utility-scale, fixed-tilt PV systems are shown by various system sizes in Table 2. U.S. benchmark capital costs for a 5MW utility-scale, fixed-tilt PV system are \$1.24/W_{DC}. Install labor costs (i.e., services provided by the construction trades) for this system are \$0.12/W_{DC} and represent 9.7 percent of total capital costs. Similar to commercial PV technologies (discussed later), average capital costs decline as the system size increases due to economies of scale.

[7] Solar water heating systems are a renewable energy technology included in Tier 1 of Maryland's RPS, however, they are not included in this analysis.
[8] Feldman, David, Vignesh Ramasamy, Ran Fu, Ashwin Ramdas, Jal Desai, and Robert Margolis, "U.S. Solar Photovoltaic System and Energy Storage Cost Benchmark: Q1 2020," National Renewable Energy Laboratory, NREL/TP-6A20-77324, January 2021, https://www.nrel.gov/docs/fy21osti/77324.pdf.
[9] Through Form EIA-860, the U.S. EIA collects detailed generation data for electric power plants with 1 MW or greater of nameplate capacity. See https://www.eia.gov/electricity/data/eia860/

Table 2: NREL 1Q 2020 U.S. Benchmark Utility-Scale Fixed-Tilt Solar PV Capital Costs, by System Size

Cost Category	5 MW	10 MW	50 MW	100 MW
Costs (2019$ per Watt DC)				
EPC/Developer Profit	0.09	0.08	0.06	0.04
Contingency	0.03	0.03	0.03	0.03
Developer Overhead	0.11	0.07	0.03	0.02
Sales Tax	0.04	0.04	0.04	0.04
Permitting, Inspection, Interconnection,	0.08	0.06	0.05	0.05
EPC Overhead	0.08	0.07	0.06	0.05
Install Labor	0.12	0.12	0.11	0.10
Electrical BOS	0.13	0.11	0.09	0.07
Structural BOS	0.10	0.10	0.09	0.08
Inverter	0.05	0.05	0.05	0.05
Module	0.41	0.41	0.41	0.41
Total Capital Costs	**1.24**	**1.14**	**1.02**	**0.94**
Costs as a Percent of Total Capital Costs				
EPC/Developer Profit	7.3%	7.0%	5.9%	4.3%
Contingency	2.4%	2.6%	2.9%	3.2%
Developer Overhead	8.9%	6.1%	2.9%	2.1%
Transmission Line (if any)	3.2%	3.5%	3.9%	4.3%
Interconnection Fee	6.5%	5.3%	4.9%	5.3%
Permitting Fee (if any)	6.5%	6.1%	5.9%	5.3%
Install Labor	9.7%	10.5%	10.8%	10.6%
Electrical BOS	10.5%	9.6%	8.8%	7.4%
Structural BOS	8.1%	8.8%	8.8%	8.5%
Inverter	4.0%	4.4%	4.9%	5.3%
Module	33.1%	36.0%	40.2%	43.6%
Total Capital Costs	100.0%	100.0%	100.0%	100.0%

Note: Based on a 100 MW utility-scale fix-tilt system using monocrystalline (19.5% efficiency) modules on a ground-mount system on driven-pile foundations. Detailed costs for transmission line (if any), interconnection fee, permitting fees, and land acquisition have been combined to more closely resemble costs details provided for commercial PV.
Source: NREL, "U.S. Solar Photovoltaic System and Energy Storage Cost Benchmark: Q1 2020," 2021, pages 42-51.

Table 3 reports U.S. benchmark capital costs for utility-scale, one-axis tracker PV systems, by various sized systems. U.S. benchmark capital costs for a 5MW utility-scale, fixed-tilt PV system are $\$1.34/W_{DC}$. Capital costs are modestly higher for this technology, compared to the fixed-tilt system. Install labor costs for this system are $\$0.13/W_{DC}$ and represent 9.7 percent of total capital costs. As per utility-scale fixed-axis and commercial PV technologies, average capital costs decline as the system size increases due to economies of scale.

In addition, capital costs or total project costs are heavily influenced by equipment (modules and inverters) and structural (foundations, and racking/mounting systems) and electrical (wiring, switches, conductors, disconnects, monitoring devices, etc.) balance of system costs. Combined, these costs represent between 55-65 percent of total project costs for utility-scale solar projects.

Table 3: NREL 1Q 2020 U.S. Benchmark Utility-Scale One-Axis Tracker Solar PV Capital Costs, by System Size

Cost Category	5 MW	10 MW	50 MW	100 MW
Costs (2019$ per Watt DC)				
EPC/Developer Profit	0.10	0.09	0.07	0.05
Contingency	0.03	0.03	0.03	0.03
Developer Overhead	0.12	0.08	0.03	0.02
Transmission Line (if any)	0.05	0.05	0.05	0.04
Sales Tax	0.08	0.04	0.04	0.05
EPC Overhead	0.09	0.09	0.07	0.06
Install Labor and Equipment	0.13	0.13	0.12	0.11
Electrical BOS	0.13	0.12	0.09	0.07
Structural BOS	0.15	0.15	0.14	0.12
Inverter	0.05	0.05	0.05	0.05
Module	0.41	0.41	0.41	0.41
Total Capital Costs	1.34	1.24	1.10	1.01
Costs as a Percent of Total Capital Costs				
EPC/Developer Profit	7.5%	7.3%	6.4%	5.0%
Contingency	2.2%	2.4%	2.7%	3.0%
Developer Overhead	9.0%	6.5%	2.7%	2.0%
Land Acquisition	3.7%	4.0%	4.5%	4.0%
Sales Tax	6.0%	3.2%	3.6%	5.0%
EPC Overhead	6.7%	7.3%	6.4%	5.9%
Install Labor and Equipment	9.7%	10.5%	10.9%	10.9%
Electrical BOS	9.7%	9.7%	8.2%	6.9%
Structural BOS	11.2%	12.1%	12.7%	11.9%
Inverter	3.7%	4.0%	4.5%	5.0%
Module	30.6%	33.1%	37.3%	40.6%
Total Capital Costs	100.0%	100.0%	100.0%	100.0%

Note: Based on a 100 MW utility-scale one-axis tracker system using monocrystalline (19.5% efficiency) modules on a ground-mount system on driven-pile foundations. Detailed costs for transmission line (if any), interconnection fee, permitting fees, and land acquisition have been combined to more closely resemble cost details provided for commercial PV.
Source: NREL, "U.S. Solar Photovoltaic System and EneCost Benchmark: Q1 2020," 2021, pages 42-51.

Table 4 (dark grey sections) shows install labor as a percent of total capital costs for various system sizes. Under both utility-scale PV systems and all system sizes, install labor costs represent about 11 percent or less of total capital costs. As such, prevailing wage legislation that increases wages and benefits for the construction trades would have a small, negligible effect on total project costs.

The bottom sections (shaded in light gray) of Table 4 shows how total capital costs change in response to various changes in install labor costs. These metrics are calculated as: install labor costs x the percentage change in install labor costs = change in total capital costs.[10] (Install labor costs are based on national average nonunion wages for electricians and laborers.)

[10] For example, suppose a project with $1.0 million in capital costs consists of $500,000 in material costs and $500,000 in install labor costs. If install labor costs were to increase 10 percent (from $500,000 to $550,000), then, all else the same, capital costs would increase by 5 percent (from $1.0 million to $1.05 million).

As shown in Table 4:

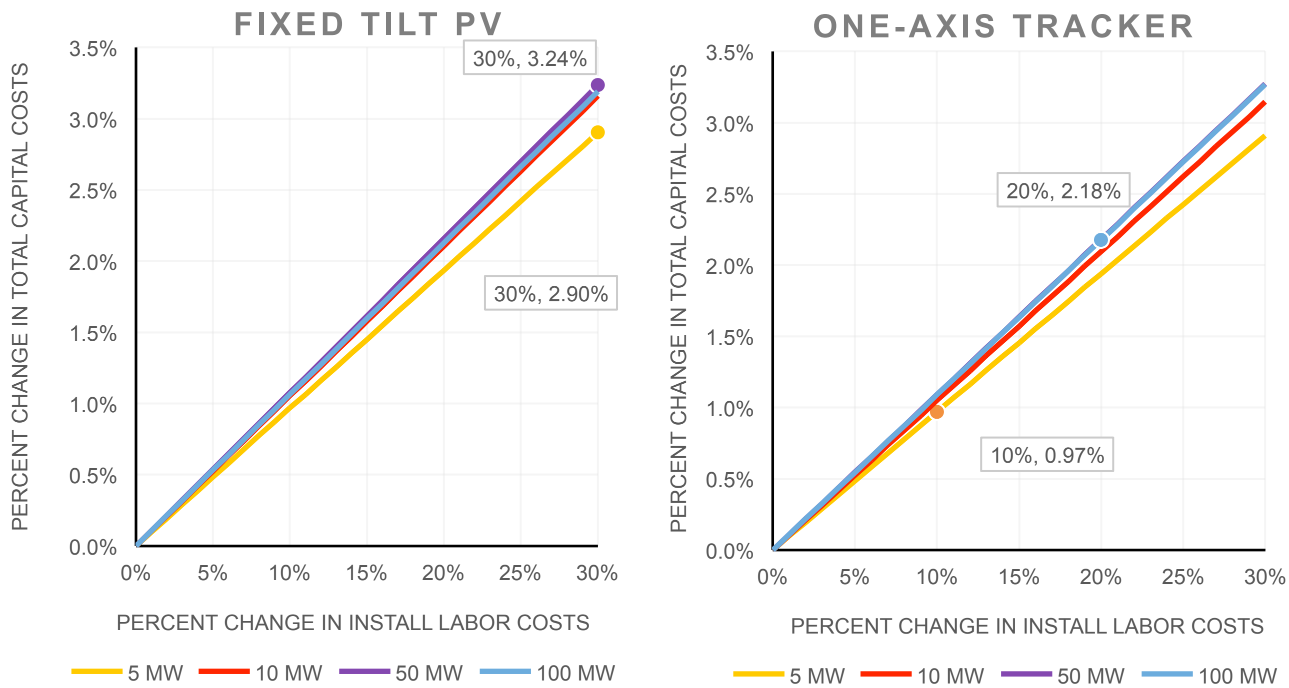
- For utility-scale, fixed-axis PV, every 1 percent increase in install labor costs results in a 0.10–0.11 percent increase in total capital costs, depending on the system size. In other words, a prevailing wage that results in a hypothetical 30 percent increase in install labor costs would increase capital costs by 2.90–3.24 percent, depending on the size of the system. (See Figure 2.)
- Similarly, for utility-scale, one-axis tracker PV, every 1 percent increase in install labor costs results in a 0.10–0.11 percent increase in total capital costs, depending on system size. In other words, a prevailing wage that results in a hypothetical 30 percent increase in install labor costs would increase capital costs by 2.91–3.27 percent, depending on the size of the system. (Also, see Figure 2.)

Table 4: Utility-Scale Fixed-Tilt PV and One-Axis Tracker PV – Sensitivity of Total Capital Costs to Changes in Install Labor Costs, by System Size

Type of System / % Change in Install Labor Costs	5 MW	10 MW	50 MW	100 MW
	Install Labor Costs as % of Total Capital			
Fixed-Tilt PV	**9.68%**	**10.53%**	**10.78%**	**10.64%**
	Percent Change in Total Capital Costs			
• 1% change in install labor costs	0.10%	0.11%	0.11%	0.11%
• 10% change in install labor costs	0.97%	1.05%	1.08%	1.06%
• 20% change in install labor costs	1.94%	2.11%	2.16%	2.13%
• 30% change in install labor costs	2.90%	3.16%	3.24%	3.19%
	Install Labor Costs as % of Total Capital			
One-Axis Tracking PV	**9.70%**	**10.48%**	**10.91%**	**10.89%**
	Percent Change in Total Capital Costs			
• 1% change in install labor costs	0.10%	0.10%	0.11%	0.11%
• 10% change in install labor costs	0.97%	1.05%	1.09%	1.09%
• 20% change in install labor costs	1.94%	2.10%	2.18%	2.18%
• 30% change in install labor costs	2.91%	3.15%	3.27%	3.27%

Source: Pinnacle Economics using U.S. Benchmarks, NREL, "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2020," 2021, pages 42-51.

Figure 2: Utility-Scale PV – Sensitivity of Total Project Costs to Changes in Install Labor Costs, by Type and Size of System (2019)



Source: Pinnacle Economics using U.S. Benchmarks, NREL, “U.S. Solar Photovoltaic System Cost Benchmark: Q1 2020,” 2021.

1.B. Commercial PV

Given the diverse customer base, building types and properties, NREL’s 1Q 2020 U.S. cost benchmarks for the commercial sector include a range of system sizes for rooftop and ground-mount PV systems using the latest monocrystalline modules (premium efficiency).

Table 5 and Table 6 report installation costs for commercial rooftop and commercial ground-mount PV systems, respectively, as reported by NREL for 1Q 2020.[11] All costs are reported in 2019 dollars per watt of direct current (W_{DC}) installed.

[11]Commercial rooftop and ground-mount solar systems consist of solar panels, inverters to convert direct current (“DC”) to alternating current (“AC”), mounting brackets, and cables. A 100kW solar system consists of approximately 280-400 panels and requires approximately 7,000 square feet of space. A 1MW solar system consists of about 4,000 panels and requires about 80,000 square feet of space (or almost 2.0 acres). Examples from Sunwatts at https://sunwatts.com.

Table 5: NREL 1Q 2020 U.S. Benchmark Commercial Rooftop PV Capital Costs, by System Size

Cost Category	100 kW	200 kW	500 kW	1 MW	2 MW
Costs (2019$ per Watt DC)					
EPC/Developer Profit	0.12	0.11	0.11	0.11	0.10
Contingency	0.05	0.04	0.04	0.04	0.04
Developer Overhead	0.36	0.33	0.31	0.31	0.30
Sales Tax	0.05	0.05	0.04	0.04	0.04
Permitting, Inspection, Interconnection	0.14	0.11	0.09	0.08	0.08
EPC Overhead	0.18	0.16	0.15	0.15	0.15
Install Labor and Equipment	0.19	0.15	0.13	0.12	0.11
Electrical BOS	0.15	0.13	0.13	0.12	0.12
Structural BOS	0.11	0.11	0.11	0.11	0.11
Inverter	0.12	0.12	0.12	0.12	0.12
Module	0.41	0.41	0.41	0.41	0.41
Total Capital Costs	1.87	1.72	1.64	1.61	1.59
Costs as a Percent of Total Capital Costs					
EPC/Developer Profit	6.4%	6.4%	6.7%	6.8%	6.3%
Contingency	2.7%	2.3%	2.4%	2.5%	2.5%
Developer Overhead	19.1%	19.2%	18.9%	19.3%	19.0%
Sales Tax	2.7%	2.9%	2.4%	2.5%	2.5%
Permitting, Inspection, Interconnection	7.4%	6.4%	5.5%	5.0%	5.1%
EPC Overhead	9.6%	9.3%	9.1%	9.3%	9.5%
Install Labor and Equipment	10.1%	8.7%	7.9%	7.5%	7.0%
Electrical BOS	8.0%	7.6%	7.9%	7.5%	7.6%
Structural BOS	5.9%	6.4%	6.7%	6.8%	7.0%
Inverter	6.4%	7.0%	7.3%	7.5%	7.6%
Module	21.8%	23.8%	25.0%	25.5%	25.9%
Total Capital Costs	100.0%	100.0%	100.0%	100.0%	100.0%

Notes: EPC stands for engineering, procurement, and construction. BOS stands for balance of system.
Source: NREL, "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2020," 2021, pages 30-41.

As shown in Table 5, U.S. benchmark capital costs for a 100kW commercial rooftop PV system are \$1.87/W_{DC}. Install labor costs[12] for this system are \$0.19/W_{DC} and represent 10.1 percent of total capital costs. Table 5 also shows that total costs and install labor costs decrease as the size of the system increases due to economies of scale. For a 2MW system, total costs are \$1.59/W_{DC} and install labor costs are \$0.11/W_{DC}, or 7.0 percent of total capital costs.

Table 6 reports U.S. benchmark capital costs for commercial ground-mount PV systems. For smaller sized systems, capital costs for ground-mount systems are modestly greater than those for rooftop systems due to higher material, equipment, and labor costs attributed to pile-driven mounting. However, ground-mount PV systems benefit more from economies of scale than rooftop PV, as their size increases the per-watt cost declines until it becomes less than rooftop PV at installations greater than 1.0 MW.

[12]NREL's direct installation labor are based on nonunion labor rates for electricians and laborers.

Table 6: NREL 1Q 2020 U.S. Benchmark Commercial Ground-Mount PV Capital Costs, by System Size

Cost Category	100 kW	200 kW	500 kW	1 MW	2 MW
Costs (2019$ per Watt DC)					
EPC/Developer Profit	0.17	0.15	0.13	0.12	0.11
Contingency	0.06	0.05	0.05	0.04	0.04
Developer Overhead	0.48	0.41	0.36	0.33	0.32
Sales Tax	0.07	0.06	0.05	0.05	0.05
Permitting, Inspection, Interconnection	0.10	0.07	0.04	0.04	0.03
EPC Overhead	0.17	0.13	0.11	0.10	0.09
Install Labor and Equipment	0.21	0.17	0.15	0.14	0.14
Electrical BOS	0.41	0.32	0.23	0.18	0.16
Structural BOS	0.17	0.14	0.12	0.11	0.11
Inverter	0.07	0.07	0.07	0.07	0.07
Module	0.41	0.41	0.41	0.41	0.41
Total Capital Costs	2.31	1.97	1.72	1.59	1.52
Costs as a Percent of Total Capital Costs					
EPC/Developer Profit	7.3%	7.6%	7.6%	7.5%	7.2%
Contingency	2.6%	2.5%	2.9%	2.5%	2.6%
Developer Overhead	20.7%	20.7%	20.9%	20.8%	20.9%
Sales Tax	3.0%	3.0%	2.9%	3.1%	3.3%
Permitting, Inspection, Interconnection	4.3%	3.5%	2.3%	2.5%	2.0%
EPC Overhead	7.3%	6.6%	6.4%	6.3%	5.9%
Install Labor and Equipment	9.1%	8.6%	8.7%	8.8%	9.2%
Electrical BOS	17.7%	16.2%	13.4%	11.3%	10.5%
Structural BOS	7.3%	7.1%	7.0%	6.9%	7.2%
Inverter	3.0%	3.5%	4.1%	4.4%	4.6%
Module	17.7%	20.7%	23.8%	25.8%	26.8%
Total Capital Costs	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Based on a 500kW commercial-scale fix-tilt ground-mount system using driven-pile foundations.
Source: NREL, "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2020," 2021, pages 30-41.

Table 7 summarizes the sensitivity of total project costs to changes in install labor costs across both commercial technologies. The top sections (shaded in dark gray) of Table 7 summarize install labor costs as a percent of total capital costs for commercial rooftop and commercial ground-mount PV systems, by various system sizes.

As shown in Table 7, based on NREL's U.S. benchmark costs, install labor costs account for between 6.96 percent (2MW system) and 10.11 percent (100kW system) of total capital costs for commercial rooftop PV, depending on the size of the system. For commercial ground-mount PV, install labor costs range from 8.59 percent (200kW system) to 9.15 percent (2 MW system). As discussed previously, the costs per-watt direct current (per unit costs) of both commercial technologies are influenced by economies of scale.

Table 7: Commercial Rooftop PV and Ground-Mount PV – Sensitivity of Total Project Costs to Changes in Install Labor Costs, by System Size

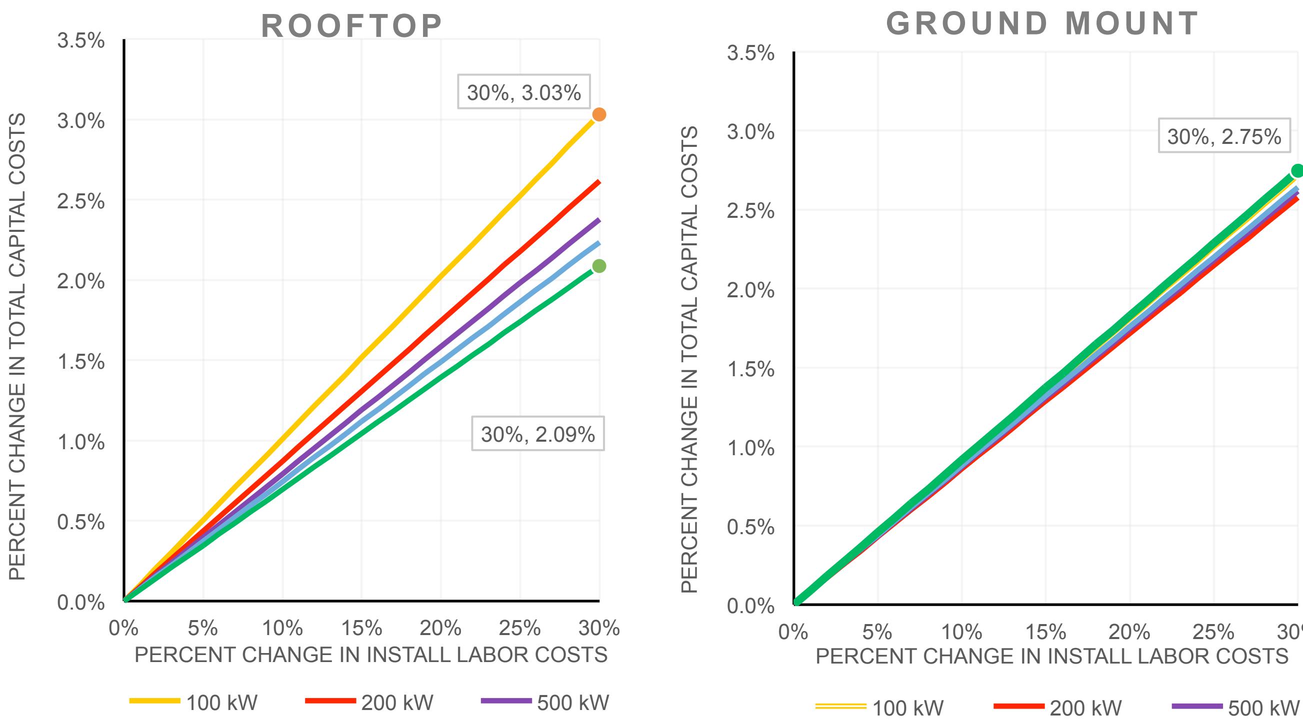
Type of System / % Change in Install Labor Costs	100 kW	200 kW	500 kW	1 MW	2 MW
	Install labor costs as % of total capital costs				
Commercial Rooftop PV	**10.11%**	**8.72%**	**7.93%**	**7.45%**	**6.96%**
	Percent Change in Total Capital Costs				
• 1% change in install labor costs	0.10%	0.09%	0.08%	0.07%	0.07%
• 10% change in install labor costs	1.01%	0.87%	0.79%	0.75%	0.70%
• 20% change in install labor costs	2.02%	1.74%	1.59%	1.49%	1.39%
• 30% change in install labor costs	3.03%	2.62%	2.38%	2.24%	2.09%
	Install labor costs as % of total capital costs				
Commercial Ground-Mount PV	**9.05%**	**8.59%**	**8.72%**	**8.81%**	**9.15%**
	Percent Change in Total Capital Costs				
• 1% change in install labor costs	0.09%	0.09%	0.09%	0.09%	0.09%
• 10% change in install labor costs	0.91%	0.86%	0.87%	0.88%	0.92%
• 20% change in install labor costs	1.81%	1.72%	1.74%	1.76%	1.83%
• 30% change in install labor costs	2.72%	2.58%	2.62%	2.64%	2.75%

Sources: Pinnacle Economics using U.S. Benchmarks, NREL, "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2020," 2021, pages 30-41.

For both commercial PV systems, across all system sizes, install labor costs represent about 10 percent or less of total capital costs. As such, prevailing wage legislation that increases wages and benefits for the construction trades would have a small, negligible effect on total capital costs. For example,

- For commercial rooftop PV, every 1 percent increase in install labor costs results in a 0.07–0.10 percent increase in total capital costs, depending on the system size. In other words, a prevailing wage that results in a hypothetical 30 percent increase in install labor costs would increase capital costs by 2.09–3.03 percent, depending on the size of the system. (See Figure 3.)
- Similarly, for commercial ground-mount PV, every 1 percent increase in install labor costs results in a 0.09 percent increase in capital costs (precision lost in rounding), across all system sizes. In other words, a prevailing wage that results in a hypothetical 30 percent increase in install labor costs would increase capital costs by 2.58–2.75 percent, depending on the size of the system. (Also see Figure 3.)

Figure 3: Commercial PV – Sensitivity of Total Project Costs to Changes in Install Labor



Costs, by Type and Size of System (2019)

Source: Pinnacle Economics using NREL 1Q 2020 benchmark capital costs.

In summary, this section shows that install labor costs represent about 10 percent or less of total capital costs for both utility-based PV and commercial PV systems, across all system sizes. These estimates are reasonable, likely lower-bound estimates applicable over the next 10-year period due to the following:

- The sensitivity of PV capital costs to changes in install labor costs are mathematically determined using objective, detailed, industry-derived benchmark capital cost estimates from NREL. Mathematically, even large percentage changes to a cost component that represents a small percent of overall capital costs do not translate into large increases in total capital costs.
- These findings are based national benchmark costs. According to NREL's earlier benchmark cost study for 1Q 2018, where capital costs are compared across ten

State	Install Labor Costs as % of Total Capital Costs	% of National
MD	7.34%	84%
MA	9.42%	108%
HI	9.33%	107%
NJ	8.95%	102%
CA	8.84%	101%
NY	9.55%	109%
AZ	6.47%	74%
FL	5.95%	68%
CO	7.06%	81%
TX	6.47%	74%
U.S.	8.74%	

Source: Fu, et. al., "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018," NREL.

states for a 200kW commercial PV system, install labor costs represent 8.74 percent of total capital costs nationally, and 7.34 percent of total capital costs in Maryland.[13] In other words, for commercial PV, labor costs in Maryland are about 16 percent lower than the national average. (This is due, in part, to the overweighting of California in the national data.)

- Although there are relatively minor differences in install labor costs and total capital costs across states, the NREL 1Q 2018 cost benchmark costs for ten states show that install labor costs represent a consistently small share of total capital costs. In fact, for larger commercial rooftop solar PV, install labor costs (6.96% of total capital costs) rank in the bottom third of the eleven cost categories, behind modules (#1, 26%); developer overhead (#2, 18.99%) engineering, procurement, and construction overhead (#3, 9.49%); inverters (#4, 7.59%); electrical BOS (#5, 7.59%); and structural BOS (#6, 6.96%).
- Historical and forecast decreases in total capital costs and install labor costs for utility-scale and commercial PV are approximately equal. Between 2010 and 2018, total capital costs and install labor costs for 200kW commercial solar PV decreased by 66 percent and 50 percent, respectively. NREL forecasts future benchmark cost changes across three scenarios (conservative, moderate, and advanced). Under the moderate scenario (which is based on U.S. manufacturers' assessments), NREL forecasts that total capital costs for a 200kw commercial solar PV will decrease 48.6 percent and install labor costs will decrease by 40.0 percent by 2030. (In 2020 dollars, the total capital costs will decline from \$1.73/W_{DC} to \$0.89/W_{DC}.) This suggests that the sensitivity of total capital costs to install labor costs for future PV will not change significantly from those estimated in this study.
- This analysis does not include possible increases in worker productivity that are linked to a (higher) prevailing wage, such as lower worker turnover, better and more prevalent apprenticeship training opportunities, improved workplace safety, etc.

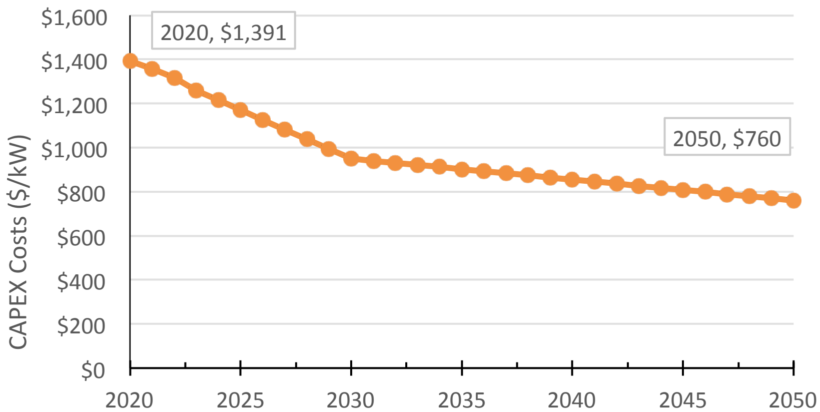
2. Utility-Scale Land-Based Wind

According to NREL, "*there is substantial focus throughout the global wind industry on driving down costs and increasing performance as a result of fierce competition from within as well as among several power generation technologies, including solar PV and natural gas-fired generation.*"[14]

Indeed, according to NREL's ATB, the costs of wind power have declined from \$2,804 per kW in 2010 to \$1,391 per kW in 2020, or by 50 percent. These historical cost decreases are expected to continue over the next three decades. NREL's moderate scenario forecast shows the costs of wind power decreasing to about \$760 per kW in 2050, representing a decrease of 45 percent from 2020 costs. (See Figure 4.) NREL's conservative and advanced scenarios show the costs of wind power decreasing by 35 percent and 62 percent, respectively over the next three decades.

[13] Fu, et. al., "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018," NREL, pages 24-27.
[14] NREL, Annual Technology Baseline ("ATB"), https://atb.nrel.gov/electricity/2021/land-based_wind, 2021.

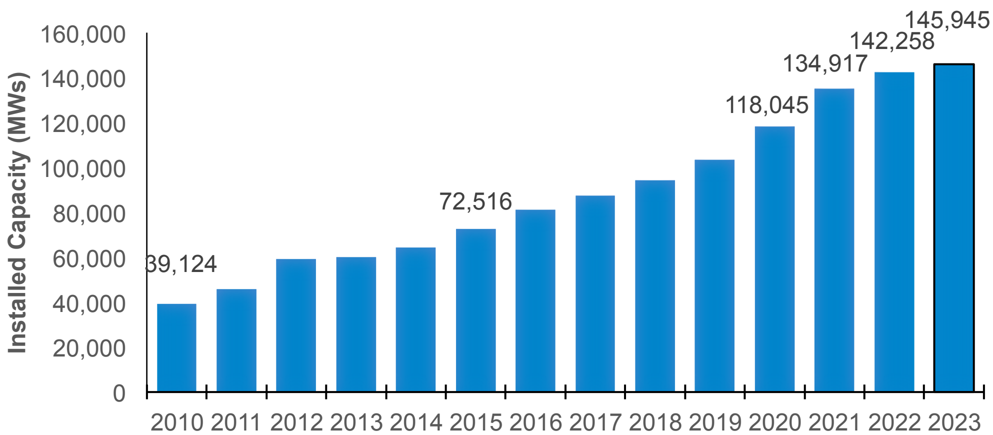
Figure 4: NREL Forecast Capital Costs for Wind Power, Moderate Scenario (2020-2050)



Source: NREL, Annual Technology Baseline, https://atb.nrel.gov/electricity/2021/land-based_wind, 2021.

As the installed costs of wind power have decreased, installed wind capacity has increased. In the electric power sector—i.e., excluding wind power capacity in other sectors— installed wind power capacity increased significantly between 2010 and 2020, and is expected to continue this growth over the next several years. (See Figure 5.) In fact, in 2019, wind power surpassed hydroelectric power as the most consumed source of renewable energy in the U.S.[15]

Figure 5: Wind Power Installed Capacity (MW), Electric Power Sector (2010-2023)



Source: U.S. Energy Information Administration ("EIA"), Short-term Energy Outlook, January 11, 2022, https://www.eia.gov/outlooks/steo/report/electricity.php.

Maryland's growing offshore wind power industry—where labor standards are in effect— provides a great example of the growth in wind power and the ability of the industry to make important economic contributions while simultaneously moving towards carbon reduction goals. According to a December 17, 2021 new release from the Maryland Public Service Commission,

[15] U.S. Energy Information Administration, "The United States consumed a record amount of renewable energy in 2020," June 16, 2021. See https://www.eia.gov/todayinenergy/detail.php?id=48396

"*Maryland's offshore wind portfolio is poised to grow substantially with a decision today by the Maryland Public Service Commission to award offshore wind renewable energy credits (ORECs) to two developers that have proposed more than 1600 megawatts of energy to be built off the coast of Maryland. Today's decision in the state's second round of offshore wind solicitations will support US Wind, Inc. and Skipjack Offshore Energy, LLC in their plans to build separate projects, together yielding nearly $1 billion in additional in-state spending and spurring the creation of more than 10,000 new direct jobs in Maryland. The new proposed projects are in addition to the 368 MW of offshore wind already being developed by both companies off Maryland's shore and whose ORECs were approved by the Commission in 2017."*

The proposals were evaluated on a number of criteria, including impacts to customer electric bills, Maryland's health, environmental and climate interests—including progress towards lowering the State's greenhouse gas emissions— and economic development benefits to the State. The Commission determined that the Round 2 projects can be built without exceeding the incremental residential and nonresidential ratepayer electric bill impact caps imposed by the Maryland General Assembly (88 cents per month for residential customers and no more than 0.9% a year for commercial and industrial customers).

In today's decision, the Commission attached numerous conditions[16] *to the approval, including requirements that the developers create a minimum of 10,324 direct jobs during the development, construction and operating phases of the projects; commit to certain goals to engage small, local and minority businesses; pass 80% of any construction costs savings to ratepayers; and contribute $6 million each to the Maryland Offshore Wind Business Development Fund. Both companies will also be required to mitigate any potential adverse environmental, noise and lighting impacts during development, construction and operation*."[17]

Utility-scale[18] wind energy includes land-based and offshore wind energy, and typically consists of large capacity turbines installed in multi-turbine wind farms connected to utility transmissions systems. This analysis focuses on the sensitivity of land-based wind energy project costs to changes in install labor costs resulting from prevailing wage laws. Similar to the broad scope of

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[16] In 2013, Maryland's Offshore Wind Energy Act ("OWEA") established Offshore Wind Renewable Energy Credits ("ORECs") to incentivize the development of offshore wind energy. In 2017, the Maryland Public Service Commission ("PSC") approved two projects that would install 368 MW of offshore wind power. In 2019, Maryland's Clean Energy Jobs Act included provisions that offshore wind energy projects must include a Community Benefit Agreement that "ensures the timely, safe, and efficient completion of the project by facilitating a steady supply of highly skilled craft workers who shall be paid not less than the prevailing wage rate determined by the commissioner of Labor and Industry…". In addition to prevailing wages for skilled construction trades, Community Benefit Agreements under Maryland's Clean Energy Jobs Act also include the following provisions: "Promotes increased opportunities for local businesses and small, minority, women-owned, and veteran-owned businesses in the clean energy industry; Promotes safe completion of the project by ensuring that at least 80% of the craft workers on the project have completed an occupational safety and health administration 10-hour or 30-hour course; Promotes career training opportunities in the construction industry for local residents, veterans, women, and minorities; Provides for best efforts and effective outreach to obtain, as a goal, the use of a workforce including minorities, to the extent practicable; and Reflects a 21st-century labor-management approach based on cooperation, harmony, and partnership." See https://legiscan.com/MD/text/SB516/2019.

[17] See https://www.psc.state.md.us/wp-content/uploads/Maryland-PSC-Decision-Expands-Offshore-Wind-Development_12172021.pdf

[18] Utility-scale, land-based wind energy does not include distributed wind energy, such as small residential wind energy projects, larger wind energy projects for commercial or institutional facilities, and community wind power projects that deliver electricity to a local community rather than into the utility transmission grid.

technologies evaluated for solar energy, this section of the report includes offshore wind energy projects.

All wind capital cost (installation or project costs) assumptions are from the National Renewable Energy Laboratory's ("NREL") U.S. benchmark studies, including the most recent benchmark study for 1Q 2020.[19] NREL uses a bottom-up approach that accounts for all installation costs from the perspective of the developer/installer, i.e., costs include profits and represent the final retail price paid to the developer/installer. NREL reports detailed benchmark "average" costs for wind energy technologies based on the following project assumptions:

- **Land-Based Reference Project.** The reference land-based wind power project consists of 79 wind turbines, each rated at 2.6 MW (based on the average wind turbine size installed in the United States in 2019) for a total capacity of 200 MW.
- **Offshore-Based Reference Project.** The reference offshore wind power project consists of 100 wind turbines rated at 6.1 MWs (the turbine capacity estimated from NREL's global offshore wind project database for calendar year 2019) for a total capacity of 600 MW. This base reference project applies to fixed-bottom and floating technologies. According to NREL, "*Turbines at the fixed-bottom reference site are assumed to be supported by a monopile substructure 50 km from cable landfall at a water depth of 34 m, which is similar to the characteristics of the wind energy areas located in the North Atlantic region. At the floating reference site, the wind turbines are assumed to be held by a semisubmersible substructure 36 km from cable landfall at a water depth of 739 m, which is analogous to features of the Pacific Coast*."[20]

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[19] Stehly, Beiter, and Duffy, "2019 Cost of Wind Energy Review," National Renewable Energy Laboratory ("NREL"), Technical Report NREL/TP-5000-78471, December 2020.
[20] Ibid.

Table 8: NREL 2019 U.S. Benchmark Land-Based Wind Capital Costs for a Representative Wind Project, (2019 dollars)

Component	$ / kilowatt (kW)	Percent of Total Capital Costs
Total turbine capital costs	**$991**	**69.0%**
Development and installation costs		
Development costs	$16	1.1%
Engineering and management	$18	1.3%
Foundation	$59	4.1%
Site access and staging	$44	3.1%
Assembly and installation	$44	3.1%
Electrical infrastructure	$145	10.1%
Construction financing costs	$34	2.4%
Contingency fund	$86	6.0%
Total development and installation costs	**$446**	**31.0%**
• Development and install labor costs	$89	6.2%
• Development and install non-labor	$357	24.8%
Total capital costs	$1,436	100.0%

Note: Numbers may not sum exactly due to rounding.
Sources: Capital costs from Stehly, Beiter, and Duffy, "2019 Cost of Wind Energy Review," National Renewable Energy Laboratory ("NREL"), Technical Report NREL/TP-5000-78471, December 2020. Development and install labor and non-labor costs from Mayfield and Jenkins, "Influence of High Road Labor Policies and Practices On Renewable Energy Costs, Decarbonization, Pathways, and Labor Outcomes," working paper, https://netzeroamerica.princeton.edu/img/Working_Paper-High_Road_Labor_and_Renewable_Energy-PUBLIC_RELEASE-4-13-21.pdf

As shown in Table 8, U.S. benchmark capital costs for a representative, land-based wind power project in 2019 are $1,436 per installed kW. Total turbine capital costs represent 69.0 percent of total project costs, while total development and installation costs account for 31.0 percent of total project costs. Install labor costs represent a subset of development and installation costs. Install labor costs amount to $89 per kW, and represent approximately 6.2 percent of total capital costs.

Table 9 reports the U.S. benchmark capital costs for a representative, offshore wind power project for fixed-bottom and floating wind power technologies. Compared to land-based wind power, total turbine capital costs account for a much smaller proportion of total project costs (31.9 percent for fixed-bottom and 24.4 percent for floating), while total development and installation costs account for a much larger proportion of total project costs (68.1 percent for fixed-bottom and 75.6 percent for floating). Nevertheless, install labor costs represent a modest proportion of total project costs at 9.3 percent for fixed-bottom and 10.3 percent for floating.

Table 9: NREL 2019 Offshore Wind Capital Costs for a Representative Wind Project, (2019 dollars)

Component	Fixed-Bottom $ / kilowatt (kW)	Fixed-Bottom Percent of Total Capital Costs	Floating $ / kilowatt (kW)	Floating Percent of Total Capital Costs
Total turbine capital costs	**$1,301**	**31.9%**	**$1,301**	**24.4%**
Development and installation costs				**0.0%**
Development costs	$138	3.4%	$165	3.1%
Engineering and management	$70	1.7%	$85	1.6%
Substructure and foundation	$817	20.0%	$1,438	27.0%
Port and staging, logistics, transportation	$58	1.4%	$44	0.8%
Electrical infrastructure	$761	18.7%	$979	18.4%
Assembly and installation	$198	4.9%	$439	8.2%
Lease price	$88	2.2%	$88	1.7%
Insurance during construction	$44	1.1%	$52	1.0%
Decommissioning bond	$58	1.4%	$76	1.4%
Construction financing	$183	4.5%	$221	4.1%
Contingency	$316	7.8%	$389	7.3%
Plant commissioning	$44	1.1%	$52	1.0%
Total development and installation costs	**$2,775**	**68.1%**	**$4,028**	**75.6%**
• Development and install labor costs	$381	9.3%	$550	10.3%
• Development and install non-labor costs	$2,394	58.7%	$3,478	65.3%
Total capital costs	**$4,076**	**100.0%**	**$5,329**	**100.0%**

Note: Numbers may not sum exactly due to rounding.
Sources: NREL, "2019 Cost of Wind Energy Review," December 2020. Mayfield and Jenkins, "Influence of High Road Labor Policies and Practices On Renewable Energy Costs, Decarbonization, Pathways, and Labor Outcomes," working paper, April 2021.

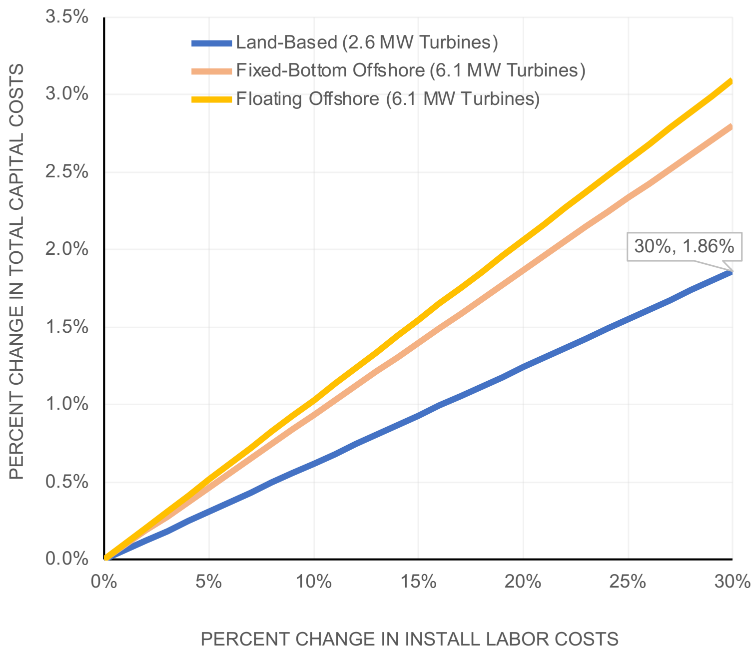
Install labor costs represent 6.2 percent for land-based wind (the subject of this study and potentially future prevailing wage laws). As such, prevailing wage legislation that increases wages and benefits for skilled trades working on utility-scale, land-based wind projects would have a small, negligible effect on total capital costs.

Table 10: Utility-Scale Land-Based and Offshore Wind – Sensitivity of Total Project Costs to Changes in Install Labor Costs for Representative Projects (2019)

% Change in Install Labor Costs	Land-Based 2.6 MW Turbine	Fixed-Bottom Offshore 6.1 MW Turbine	Floating Offshore 6.1 MW Turbine
	Install labor costs as % of total capital costs		
	6.21%	**9.34%**	**10.32%**
	Percent Change in Total Capital Costs		
• 1% change in install labor costs	0.06%	0.09%	0.10%
• 10% change in install labor costs	0.62%	0.93%	1.03%
• 20% change in install labor costs	1.24%	1.87%	2.06%
• 30% change in install labor costs	1.86%	2.80%	3.09%

Sources: NREL, "2019 Cost of Wind Energy Review," December 2020. Mayfield and Jenkins, "Influence of High Road Labor Policies and Practices On Renewable Energy Costs, Decarbonization, Pathways, and Labor Outcomes," working paper, April 2021.

Figure 6: Land-Based and Offshore Wind – Sensitivity of Total Project Costs to Changes in Install Labor Costs, by Type of Project (2019)



Sources: NREL, "2019 Cost of Wind Energy Review," December 2020. Mayfield and Jenkins, "Influence of High Road Labor Policies and Practices On Renewable Energy Costs, Decarbonization, Pathways, and Labor Outcomes," working paper, April 2021.

3. Geothermal

Geothermal energy is a renewable energy resource that uses the earth's heat to generate electricity and heat buildings. The advantages of geothermal as an energy resource include: it is abundant,[21] renewable and unvarying as the earth continuously produces heat, it is clean as most modern closed-loop geothermal plants emit no greenhouse gases and consume less water than other conventional energy sources,[22] it is domestic and can be found throughout the U.S., and it casts a relatively small footprint.

Going forward, geothermal energy represents an important emerging technology to accommodate a decarbonization future. Technological improvements that lower costs and improve geothermal economics could lead to greater, widespread adoption of geothermal energy. Indeed, an analysis conducted by the U.S. Department of Energy's Geothermal Technology Office (the "GeoVision" analysis) concludes that new technologies have the potential to lead to a 26-fold increase in geothermal electric generation capacity in 2050, when

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[21] According to the International Renewable Energy Agency ("IRENA"), "The amount of heat within 10,000 meters of the earth's surface is estimated to have more 50,000 times more energy than all of the oil and natural gas resources worldwide." See IRENA, "Geothermal Power Technology Brief," page 2, September 2017.

[22] Argonne National Lab, "Life Cycle Analysis Results of Geothermal Systems in Comparison to Other Power Systems," Figure 16, page 43, August 2010.

geothermal capacity could reach 60 GWs of capacity or provide approximately 8.5 percent of U.S. electricity generation.[23]

The type of geothermal technology used depends, in large part, on the heat content of the geothermal field. This analysis covers two technologies that represent approximately 60 percent of installed geothermal capacity in the U.S. in 2020, and basically all of the new geothermal capacity added since 1985:

- Flash plants account for about 30 percent of installed geothermal capacity in the U.S. in 2020.[24] Flash plants extract steam through a process called "flashing". This steam is then fed into turbines to generate electricity. This technology works best with temperatures greater than 200 degrees Celsius. Flash plants vary in size (0.2 to 150 MW) depending on whether they are single, double, or triple flash. (Flash plants are similar to dry steam plants. Dry steam plants represent about 40 percent of installed geothermal capacity in the U.S. in 2020, but installed capacity has not increased since the mid-1980s so this technology is not included in this analysis.)
- Binary plants are used when the heat content of the geothermal field is lower, i.e., less than 180-200 degrees Celsius. At these lower temperatures, the resource fluid is used in combination with heat exchangers to heat the process fluid, which is then fed into turbines and generators to make electricity. Binary plants represent about 30 percent of installed geothermal capacity in the U.S. in 2020.

This analysis relies on detailed cost data for flash and binary geothermal plants developed by the Electric Power Research Institute ("EPRI") and reported in Table 11.[25] Importantly, install labor costs are based on union-workers receiving prevailing wages. As a result, this section reports install labor costs but does not measure the sensitivity of project costs to changes in install labor costs. Install labor costs represent 8.0 percent of total plant costs for a 50 MW, bottom exhaust flash plant; 7.6 percent of total plant costs for a 40 MW, top exhaust flash plant; and 3.0 percent of total plant costs for a 50 MW binary plant.

[23] U.S. Department of Energy's Geothermal Technology Office, "Geovision," see https://www.energy.gov/eere/geothermal/geovision
[24] Robins, et. al., "2021 U.S. Geothermal Power Production and District Heating Market Report, National Renewable Energy Laboratory ("NREL"), 2021.
[25] McGowin, "Engineering and Economic Evaluation of Geothermal Power Plants," Technical Update, Electric Power Research Institute ("EPRI"), December 2010.

Table 11: Geothermal Power Plant Installed Costs, by Plant Technology, 2010 (nominal dollars)

Phase/Item	50 MW Flash Plant (bottom exhaust) Cost	% of TPC	40 MW Flash Plant (top exhaust) Cost	% of TPC	50 MW Binary Plant Cost	% of TPC
Resource identification	$818,000	0.3%	$658,000	0.3%	$864,000	0.3%
Well field	$85,000,000	34.9%	$70,000,000	34.9%	$100,000,000	37.7%
Gathering system	$27,360,000	11.2%	$22,104,000	11.0%	$32,976,000	12.4%
Power plant	$87,212,000	35.9%	$71,457,000	35.7%	$95,012,000	35.9%
• Equipment	$45,670,000	18.8%	$37,125,000	18.5%	$73,924,000	27.9%
• Materials	$22,010,000	9.0%	$19,149,000	9.6%	$13,086,000	4.9%
• Labor	$19,532,000	8.0%	$15,183,000	7.6%	$8,002,000	3.0%
a) Equipment	$2,709,300	1.1%	$2,020,000	1.0%	$96,300	0.0%
b) Piping	$5,871,000	2.4%	$4,137,300	2.1%	$2,418,700	0.9%
c) Civil	$7,327,800	3.0%	$5,857,400	2.9%	$2,560,500	1.0%
d) Steel	$493,300	0.2%	$438,000	0.2%	$821,600	0.3%
e) Instruments	$974,300	0.4%	$847,900	0.4%	$569,800	0.2%
f) Electrical	$1,343,900	0.6%	$1,205,900	0.6%	$1,055,700	0.4%
g) Insulation	$396,100	0.2%	$341,300	0.2%	$454,700	0.2%
h) Paint	$416,300	0.2%	$335,400	0.2%	$24,700	0.0%
Indirect costs (EPC contract basis)	$42,860,000	17.6%	$36,088,000	18.0%	$36,088,000	13.6%
Total plant costs (TPC)	$243,250,000	100.0%	$200,307,000	100.0%	$264,940,000	100.0%

Notes: 1. Values may not sum exactly due to rounding. 2. EPC = Engineering, Procurement, and Construction
Source: McGowin, "Engineering and Economic Evaluation of Geothermal Power Plants," Technical Update, Electric Power Research Institute ("EPRI"), December 2010.

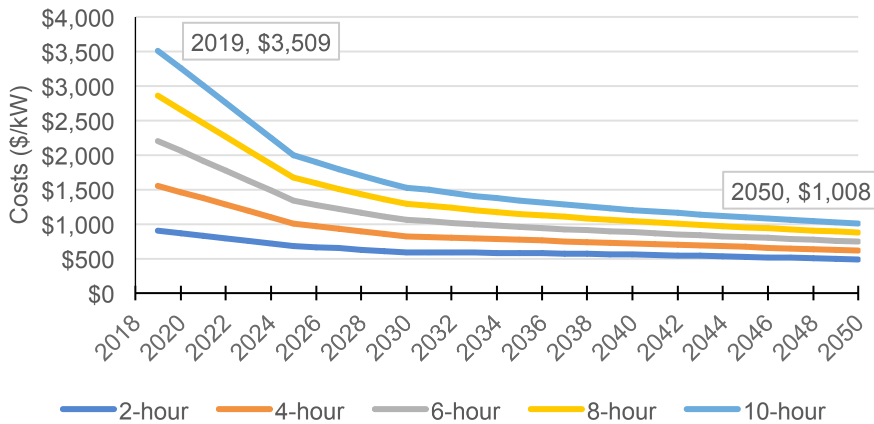
4. Energy (Battery) Storage Systems

Utility-scale energy (battery) storage systems represent a promising technology that will help bridge the imbalance between energy supply and energy demand attributed to the intermittency of renewable energy resources such as solar and wind. Driven by falling prices and technological improvements that allows batteries to store more energy, utility-scale energy storage systems are experiencing significant growth. This growth is expected to continue as battery energy storage system costs continue to fall.

- According to the U.S. Energy Information Administration ("EIA"), average installed utility-scale energy storage costs decreased by almost 70 percent between 2015 and 2018.[26]
- NREL's Moderate Technology Innovation Scenario (moderate scenario) forecasts cost decreases of between 46 percent and 71 percent, depending on battery storage duration, for 60MW utility-scale energy storage systems between 2018 and 2050. (See Figure 7.)[27]

[26] U.S. Energy Information Administration, "Annual Electric Generator Report," https://www.eia.gov/todayinenergy/detail.php?id=45596&src=email
[27] NREL, Annual Technology Baseline, 2018-2050, https://atb.nrel.gov/electricity/2021/utility-scale_battery_storage.

Figure 7: Cost Projections for a Utility-Scale 60 MW Lithium-Ion Battery Energy Storage System of Various Battery Durations (Hours), Moderate Scenario, (2018 dollars)



Source: NREL, Annual Technology Baseline, 2018-2050.

This analysis relies on detailed, cost data obtained from the NREL for a utility-scale, stand-alone energy storage system based on a lithium-ion, 60 MW_{DC} battery and inverters (2.5 MW per inverter), and four hour battery duration. (This cost breakdown is approximately the same across various battery durations, as well as for commercial projects.) Install labor costs are based on national average wages for non-union laborers and electricians.

Table 12: NREL Detailed Cost Breakdown for a 60 MW Utility-Scale, Lithium-ion Stand Alone Energy Storage System with Battery Duration of 4 hours (2019)

Model Component	Total Cost ($)	% of Total Cost
Lithium-ion Battery	$46,560,000	56.3%
Battery Central Inverter	$3,600,000	4.4%
Structural BOS	$3,173,302	3.8%
Electrical BOS	$8,599,517	10.4%
Install Labor & Equip	$4,694,348	5.7%
EPC Overhead	$2,354,557	2.8%
Sale Tax	$3,807,403	4.6%
Total EPC Costs	**$72,789,127**	**88.0%**
Land acquisition	$0	0.0%
Permitting fee	$295,289	0.4%
Interconnection fee	$1,849,475	2.2%
Contingency	$2,265,787	2.7%
Developer overhead	$1,603,157	1.9%
EPC/developer net profit	$3,940,146	4.8%
Total Developer Costs	**$9,953,854**	**12.0%**
Total System Costs	**$82,742,981**	**100.0%**

Source: Feldman, David, Vignesh Ramasamy, Ran Fu, Ashwin Ramdas, Jal Desai, and Robert Margolis, "U.S. Solar Photovoltaic System and Energy Storage Cost Benchmark: Q1 2020," National Renewable Energy Laboratory, NREL/TP-6A20-77324, https://www.nrel.gov/docs/fy21osti/77324.pdf.

As is shown in Table 12, install labor and equipment represents just 5.7 percent of the total cost of a 60 MW utility-scale, battery storage system. As such, prevailing wage legislation that increases wages and benefits for construction trades working on energy storage projects would have a small, negligible effect on total capital costs.

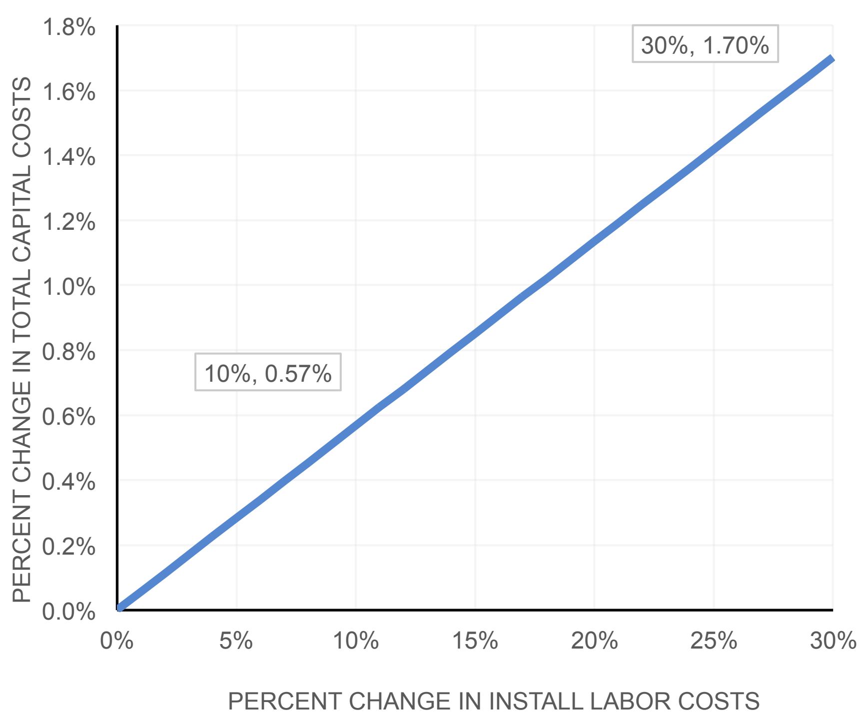
Table 13: Utility-Scale Energy Storage Systems – Sensitivity of Total Project Costs to Changes in Install Labor Costs (2019)

% Change in Install Labor Costs	Utility-Scale 60 MW Energy Storage
Install labor costs as % of total capital costs	**5.67%**
Percent Change in Total Capital Costs	
• 1% change in install labor costs	0.06%
• 10% change in install labor costs	0.57%
• 20% change in install labor costs	1.13%
• 30% change in install labor costs	1.70%

Source: NREL, "U.S. Solar Photovoltaic System and Energy Storage Cost Benchmark: Q1 2020," 2021.

For a 60 MW utility-scale energy storage system, every 1 percent increase in install labor costs results in a 0.06 percent increase in total project costs. A prevailing wage law that results in a hypothetical 30 percent increase in installed labor costs would increase total project costs by about 1.70 percent.

Figure 8: Utility-Scale Energy Storage Systems – Sensitivity of Total Project Costs to Changes in Install Labor Costs (2019)



Source: NREL, "U.S. Solar Photovoltaic System and Energy Storage Cost Benchmark: Q1 2020," 2021