MaxSpan™ PILE DRIVEN SYSTEMS

GAMECHANGE SOLAR
REPOWERING THE PLANET

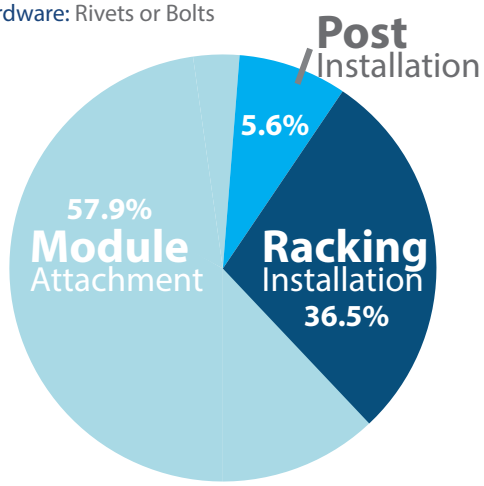
TIME STUDY
USING BOLTS AND RIVETS

System Type:
MaxSpan™ FastBuild Pile Driven System
System Size:
83.2MW in a group of 8 sub-projects
(28.5MW bottom mount riveted, 54.7MW bolted)

EPC/Installer: Leading Nationwide Installer
Modules: 298.9 watt average, a blend of Jinko, Trina, JA Solar and Canadian Solar (300.9 watt average riveted mounted modules, 297.9 watt average bolted)
Location: Wilson, North Carolina
Site Conditions: Varied from level to undulating, sometimes severe
Time frame: : October 2016 through March 2017
Weather Conditions: Typical North Carolina fall and winter weather
Installer familiarity with System: First time
Module Mounting Hardware: Rivets or Bolts

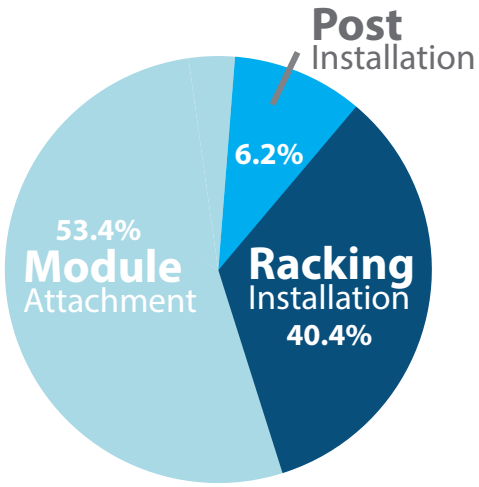
USING BOLTS

	Man Hours Per Module Equivalent (%)	Man Hours Per MW (297.9W modules)	Man Hours Per Module Equivalent (Hours)	NOT Including Movement of Material from Staging Area Man Hours Per Module Equivalent (Hours)
Module Attachment	57.9%	254	0.0756	0.0567
Post Installation	5.6%	25	0.0074	0.0062
Racking Installation	36.5%	160	0.0476	0.0455



USING RIVETS

	Man Hours Per Module Equivalent (%)	Man Hours Per MW (297.9W modules)	Man Hours Per Module Equivalent (Hours)	NOT Including Movement of Material from Staging Area Man Hours Per Module Equivalent (Hours)
Module Attachment	53.4%	209	0.0630	0.0567
Post Installation	6.2%	24	0.0074	0.0062
Racking Installation	40.4%	158	0.0476	0.0455



STUDY RESULTS

The study concludes that the installation rate including moving materials from staging area for the installation period studied for a 6.8 actual hour workday was:

For mounting modules with rivets:

.1180 man hours per module equivalent
20 men system installation rate: 1.734MW per week

For mounting modules with bolts:

.1306 man hours per module equivalent
20 men system installation rate: 1.551MW per week

GAMECHANGE SOLAR
REPOWERING THE PLANET

ABOUT THE STUDY

Study focus: Task 1: movement from staging area and installation of piles. Task 2: movement from staging area and installation of beams, braces, purlins, roll ties, purlin straps and purlin angles. Task 3: movement from staging area and installation area of PV modules with rivets and star washers or with bolts, serrated flange nuts and star washers (one per module).

Please note that installation rate may vary from site to site and installer to installer. It is advisable to receive training from GameChange personnel for first time installers of GameChange systems.

The following time study project was conducted to develop a valid assessment of the work content of the labor related to installation tasks in terms of Hours spent on each task and total hours spent per module equivalent for installation of the completed system.

The study was primarily conducted by interviewing site supervisors regarding workplace production on hourly and daily basis with employees Assigned to perform specific tasks. Hours noted were actual hours worked and were not adjusted for the typical 20% loss factor related to hours actually performing tasks versus recorded hours for payroll timesheets. For example the 6.8 hours worked shows a typical work day, but worker pay would be based on an 8 hour work day.

The study analyzes each operation in terms of completed units, each unit being one installed module equivalent.

STUDY DETAILS

The employee work hours were studied relating to three principal installation tasks.

Task 1: Movement of Piles from Staging Area and Installation of Piles

This task consists of driving posts at marked locations on the site. One team of three men conducted layout of 1,300 piles per 6.8 hour work day, one man driving tracked skidsteer backwards, other two men unloading piles at rooster tail flag locations.

Pile driving team of one pile driving machine operator and two men drove piles at rooster tail flag locations and moved to next pile location at rate of 1 minute and 40 seconds per pile average, or 244.8 per 6.8 hour work day.

Man hours per module equivalent for pile, which supported 13.443 modules average

= (3 men x 6.8 hours + 3 men x 6.8 hours x 244.8/1,300) / (244.8 posts x 13.443 modules per post) = 0.0074 man hours per module equivalent

For installation only, not including staging, installation rate

= (3 men x 6.8 hours) / (244.8 posts x 13.443 modules per post) = 0.0062 man hours per module equivalent

---

Task 2: Movement from Staging Area and Installation of Beams, Braces, Purlins, Roll Ties, Purlin Angles and Purlin Straps

One team of three men did layout of 640 beams and braces in half of one 6.8 hour work day with one man driving tracked skidsteer backwards and other two men unloaded piles at pile locations.

Two man crew installed 640 sets of beams and braces per 6.8 hour workday (8,603.7 module equivalents)

One team of three men did layout of 6mw (20,275.5 module equivalents) of purlins, roll ties, purlin angles and roll straps in one 6.8 hour work day, one man driving tracked skidsteer backwards, other two men unloading between pile locations.

Three four man crews installed 1.1mw (3,717 module equivalents) per day purlins, roll ties, purlin angles and purlins straps. First crew attached purlins. Second crew attached roll ties, purlin angles and roll straps finger tight and the third crew did alignment, squaring, torque to specification and torque marking.

Man hours per module equivalent for movement from staging area and installation of beams, braces, purlins, roll ties, purlin angles and purlins straps:

Task 2 (continued):

= (3 men x 3.4 hours) / (640 x 13.443 modules) + (2 men x 6.8 hours) / (8,603.7 modules) + (3 men * 6.8 hours) / 20275.5 + (24 men x 6.8 hours) / (3,717 modules) = .0477 man hours

For installation only, not including staging, installation rate estimated

= (2 men x 6.8 hours) / (8,603.7 modules) + (24 men x 6.8 hours) / (3,717 modules) = .0455 man hours

---

Task 3: Mounting of PV Modules

This task consists of moving from staging area and mounting of modules onto purlins from below.

For sites utilizing rivets:
This included inserting rivet from below purlin and then through the module frame and then placing star washer on rivet, and then placing washer on rivet, and then pulling rivet with rivet gun at one location per module. At other three locations per module this procedure was conducted Without using the star washer.

A twenty man crew completed the installation of the 2,160 modules per day, Working 6.8 hours per day actual work rate.

Four man crews would have one man running rivet gun, two men moving modules to position on racks, and one man breaking open boxes. Three man QC team followed, two men grabbed and shook modules to make sure all rivets tight, one man went under, used chisel to pop off any loose rivets and reinstalled new rivet using battery powered rivet gun.

Man hours per module equivalent for mounting of PV modules

= (20 men x 6.8 hours) / (2,160) = 0.063 man hours
For installation only, not including staging, installation rate estimated at 90% of total rate including staging = .057 man hours

For sites utilizing Bolts:
This included inserting Bolt from below purlin, then through the module frame, then placing star washer on bolt. Then, place serrated flange nut on bolt and hold nut with finger attaching bolt to rated torque with driver. At the other three locations per module, this procedure was conducted without using the star washer. Final step was the QC team would follow, check every bolt with torque wrench to make sure to specification, and then add torque mark with black Sharpie.
A twenty four man crew completed the installation of the 2,160 modules per day, working 6.8 hours per day actual work rate.
Man hours per module equivalent for mounting of PV Modules

= (24 men x 6.8 hours) / (2,160) = 0.076 man hours
For installation only, not including staging, installation rate estimated at 90% of total rate including staging = .068 man hours