

## TIME STUDY

**System Type:**  
Pour-in-Place™  
Ballasted Ground System  
with Round Tubs

**System Size:**  
2.062 MW site,  
320 watt modules

**Study Focus:** Purlin Support Assembly,  
Installation of Pour-in-Place™ with round  
tubs, racks, concrete, and PV modules

**Location:** West Boylston MA, Landfill Site

**Site Conditions:** Relatively level

**Time frame:** October - November 2016

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**Weather Conditions:** Typical Massachusetts  
rainy fall weather, average temperature 40 deg F

**Installer familiarity with System:** First Time

**Module Mounting Hardware:** Bolts, serrated  
flange nuts and star washers

## STUDY RESULTS

The study concludes that the installation rate per module equivalent of the GC Pour-in-Place™ ballasted ground system using round tubs for the installation period studied was:

**.1323 man hours per module equivalent when pouring into tubs utilizing overhead hose on boom fed from concrete pump truck.**

Number of modules and system installed hourly: 151.2  
Per 8 work hour day: 1209.4  
Per 6.8 work hour day: 1028.0

20 men weekly install rate (8 hour day): 1.94MW  
20 men weekly install rate (6.8 hour day): 1.64MW

**.1565 man hours per module equivalent when utilizing pouring from concrete trucks directly into tubs.**

Number of modules and system installed hourly: 127.8  
Per 8 work hour day: 1022.5  
Per 6.8 work hour day: 869.1

20 men weekly install rate (8 hour day): 1.64MW  
20 men weekly install rate (6.8 hour day): 1.39MW

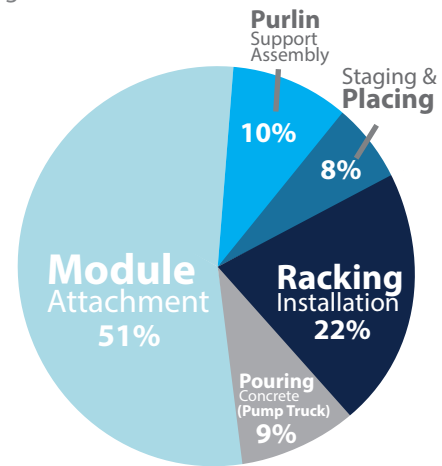
**.1664 man hours per module equivalent when utilizing bobcats pouring from buckets and reloading from concrete trucks offsite.**

Number of modules and system installed hourly: 120.2  
Per 8 work hour day: 961.4  
Per 6.8 work hour day: 817.2

20 men weekly install rate (8 hour day): 1.54MW  
20 men weekly install rate (6.8 hour day): 1.31MW

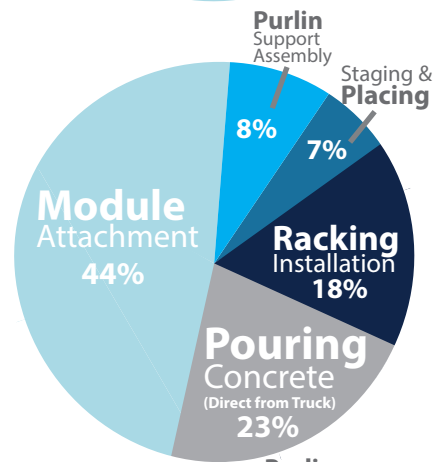
### System Installation Pouring into Tubs Utilizing Overhead Hose on Boom Fed from Concrete Pump Truck:

	Man Hours Per Module Equivalent (%)	Man Hours Per MW (320W modules)	Man Hours Per Module Equivalent (Hours)
Purlin Support Assembly	10%	41	0.0132
Placing & Staging	8%	32	0.0102
Racking Installation	22%	90	0.0287
Pouring Concrete	9%	38	0.0122
Module Attachment	51%	213	0.0680



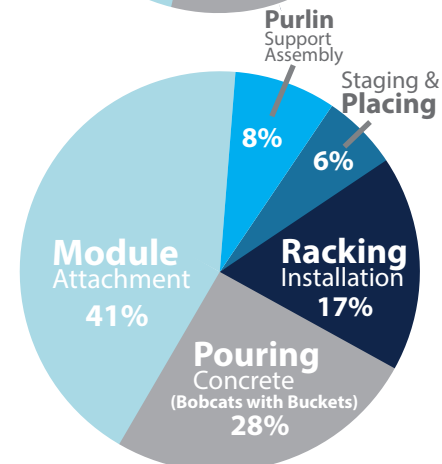
### System Installation Utilizing Concrete Pouring Directly from Concrete Truck:

	Man Hours Per Module Equivalent (%)	Man Hours Per MW (320W modules)	Man Hours Per Module Equivalent (Hours)
Purlin Support Assembly	8%	41	0.0132
Placing & Staging	7%	32	0.0102
Racking Installation	18%	90	0.0287
Pouring Concrete	23%	114	0.0364
Module Attachment	44%	213	0.0680



### System Installation Utilizing Bobcats with Buckets Pouring into Tubs Reloading from Concrete Trucks:

	Man Hours Per Module Equivalent (%)	Man Hours Per MW (320W modules)	Man Hours Per Module Equivalent (Hours)
Purlin Support Assembly	8%	41	0.0132
Placing & Staging	6%	32	0.0102
Racking Installation	17%	90	0.0287
Pouring Concrete	28%	145	0.0463
Module Attachment	41%	213	0.0680



## SUMMARY

The following time study was conducted to develop a valid assessment of the work content of the labor required for installation tasks in terms of hours spent on each task and total hours spent per module equivalent for installation of the completed system. This consists of purlin support assembly, installation of Pour-in-Place tubs, racks and concrete utilizing bobcats with pouring buckets fed from concrete trucks at edge of site. This study also shows estimated installation rates based on other sites utilizing two other methods: concrete pump truck pouring using overhead hose on boom and pouring directly from concrete truck, and PV module install.

## ABOUT THE STUDY

The study was conducted by interviewing project managers on employee production rates for performing specific tasks. Hourly production rates noted were actual hours worked on performing the tasks. The purpose of the study was to analyze the employee time spent for each task up to the total time for installation of the completed system. This consists of purlin support assembly, installation of Pour-in-Place™ tubs, racks, concrete, and pv modules. 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 five principal installation tasks.

### Task 1: Purlin Support Assembly

An effective approach was to assemble the purlin supports in different areas of the array to minimize transportation of the completed purlin support assemblies.

This task consists of utilizing an assembly jig to bolt together galvanized steel components with bolts and flange nuts. Two men assembled one purlin support four minutes each. Each purlin support assembly can support 10.116 modules.

Man hours per module equivalent for purlin support assembly:  
**= (2 man x 6.8 hours) / (6.8 man hours x 15 per hour x 10.116 modules equivalents per Assembly) = 0.0132 man hours**

### Task 2: Placing (Staging) Pour-in-Place™ tubs, Purlin Support Assemblies, Purlins, and other Racking Components

This task consists of placing (staging) Pour-in-Place™ tubs approximately every 16 feet along with purlin support assemblies and all other racking components.

A four man team with two more men as bobcat operators and two bobcats installed four rows per 6.8 work hour day. An average row supported 146.455 modules and 14.477 purlin support assemblies with two round Pour-in-Place™ tubs each.

Man hours per module equivalent for placing Pour-in-Place™ tubs, purlin support assemblies, and all other racking components:  
**= (6 men x 6.8 hours) / (4 rows per hour x 6.8 hours per day x 146.455 modules per row) = 0.0102 man hours**

### Task 3: Installing Purlin Support Assemblies, Purlins, and other Racking Components

This task consists of placing Pour-in-Place™ tubs to both sides of the string that was down the center of the row east to west. Then, placing purlin support assemblies inside Pour-in-Place™ tubs, installing purlins, purlin angles, and bend straps. Make sure square, then torque to specification. Last, install roll ties and roll straps, leave finger tight for final torque after module placement.

A four man team working an 8.7 work hour day installed 120 purlin support assemblies and related racking. Average purlin support assemblies can support 10.116 modules.

Man hours per module equivalent for placing Pour-in-Place™ tubs and installing purlin support assemblies and all other racking components:  
**= (4 men x 8.7 work hours) / (120 Purlin Support Assemblies and related racking per day x 10.116 modules per Purlin Support Assembly) = 0.0287 man hours**

### Task 4: Concrete Pouring

**Production rate when pouring into tubs utilizing overhead hose on boom fed from concrete pump truck:** This site did not use concrete pump truck method for concrete installation, however, this data is provided for comparative purposes from another typical site where this alternative method was utilized. Five men were required (concrete truck operator comes with truck and is not a cost). One man operated pump truck with two alternating teams of two men filling a row of tubs. One man used hose to fill tubs, another man with shovel and vibrator, then would pass the hose over to two man team on next row.

### Task 4: (continued)

While they filled the row of tubs, they would use trowels to clean up ones they had just poured with one man screeding off the concrete from top of tubs and one man for finishing touches. Average production rate was one concrete truck load each 20 minutes, each of which filled 35 tubs.

Each row averaged 162 modules resulting in one extra assembly for each 162 modules, or a 2.47% loss in a module equivalent basis.

Man hours per module equivalent when pouring into tubs utilizing overhead hose on boom fed from concrete pump truck on edge of site:  
**= (5 men x 6.8 hours) / (35 tubs per concrete truckload x 3 truckloads per hour x 4 modules per tub x 6.8 hours per day x 97.53%) = 0.0122 man hours**

### Production rate when utilizing concrete trucks pouring directly into tubs:

This site did not use direct pouring from truck method for concrete installation, however this data is provided for comparative purposes from another typical site where this alternative method was utilized. This method may not be used when weight is an issue on the site for locations such as capped landfills.

When utilizing concrete trucks pouring directly into tubs, five men were required (concrete truck operator comes with truck and is not a cost). One man supervised trucks as they poured into tubs, one man pushed concrete into tub ends. One man used vibrator to settle concrete around posts and into ends of tubs evenly, one man screeded off the concrete from top of tub, and one man for finishing touches. Average production rate was 6 concrete truck loads over six hours, each of which filled 35 tubs.

Each row averaged 216 modules resulting in one extra assembly for each 216 modules, or a 1.85% loss in a module equivalent basis.

Man hours per module equivalent for concrete pouring when pouring directly from concrete trucks:  
**= (5 men x 6 work hours) / (35 tubs per concrete truckload x 6 truckloads x 4 modules per tub x 98.15%) = 0.0364 man hours**

### Production rate when utilizing bobcats with buckets pouring into tubs

**reloading from offsite concrete truck:** Two bobcats with ¾ yard pouring buckets drove average distance of 400 feet back and forth from concrete truck to fill Pour-in-Place™ tubs. Two operators and three more men are required in order to fill 16 tubs avg per truckload in 45 minutes. Note-concrete truck operator comes with truck and is not a cost since free of charge by typical readi-mix concrete vendors. One man used vibrator to settle concrete around posts and into tubs evenly. One man screeded the concrete from top of tub, one man for finishing touches.

Man hours per module equivalent for concrete pouring when utilizing bobcats with ¾ yard pouring buckets reloading from concrete truck on edge of site:  
**= (5 men x 6.8 hours) / (16 tubs (or 8 Purlin Support Assemblies) x 10.116 modules per Purlin Support Assembly x (6.8 / .75 hours)) = 0.0463 man hours**

### Task 5: Module Mounting

This task consists of mounting modules onto purlins from below. This includes inserting bolt from below purlin and then through the module frame and placing star washer on bolt. Then install flange nut onto bolt and torque bolt to specification at one location. Install only bolt and flange nut at other three locations per module and torque bolts to specification.

Typical module installation rate for this method on GameChange systems has been 100 modules per man per day including staging. Man hours per module equivalent for mounting of PV modules:  
**= (1 man x 6.8 hours) / (100 modules) = 0.068 man hours**