DNV BOS COMPARISON REPORT - TEXAS

Technical Note

LONGi Solar Technology (U.S.) Inc

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SAFER, SMARTER, GREENER

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1 INTRODUCTION

LONGi Solar Technology (U.S.) Inc ("LONGi" or the "Customer") has engaged DNV Energy USA Inc. (DNV) to provide balance of system cost comparison services for three different modules and three separate layout configurations ("LONGi BOS" or the "Project"). These scenarios were studied for hypothetical projects in Texas, United States.

1.1 Background

Large format modules are a newer module technology currently being developed by module manufacturers including LONGi. These modules are larger than standard 72 or 144 cell modules and also have different electrical characteristics. Due to these differences, the standard assumptions for how to optimally design a PV array may not hold true. Numerous design factors are affected by the change to large format modules which also affects the overall balance of system costs for a project. DNV took these differences into account and ran multiple scenarios to find the cost differences between three different large format modules chosen by LONGi along with three different racking options.

2 SCENARIOS

Table 2-1 describes the modules that were used for the cost comparison analysis.

Table 2-1 Modules studied

Module Type	Power (W)	Voc (V)	Isc (A)	Length (mm)	Width (mm)	Thickness (mm)	Area (m^2)	Weight (kg)
182-72c	540	49.5	13.85	2256	1133	35	2.556048	32.3
210-55c	545	37.7	18.3	2384	1096	35	2.612864	32.6
210-60c	595	41.5	18.36	2172	1303	35	2.830116	35.3

The following scenarios were studied:

- Scenario 1: A single-axis tracker system with one module high in portrait orientation (1P). Three layouts were designed: one for each module type.
- Scenario 2: A fixed tilt racking system with two modules high in portrait orientation (2P). Two layouts were designed using the 182-72c and 210-60c modules.
- Scenario 3: A fixed tilt racking system with four modules high in landscape orientation (4L). Two layouts were designed using the 182-72c and 210-55c modules

3 PROCESS

Costs for various aspects of the project were calculated based on industry research, equipment manufacturer quotes, and DNV experience. DNV used an approximately 3.7 MWdc power block as a basis for its calculations, designing multiple layouts for the racking and module scenarios. Once a layout was designed, DNV then found design parameters necessary to calculate the balance of system costs requested by LONGi. All costs are calculated in 2021 United States Dollars.

Wood Mackenzie is an industry research company that aggregates data from hundreds of solar projects throughout the United States and the world to come up with typical costs for specific project parameters. These costs can be filtered by state, project size, and equipment type to accurately reflect the costs of a particular project design. DNV relied on these figures [1] to find costs for particular project parameters and supplemented this information with quotes from equipment manufacturers to come up with accurate final costs.

3.1 Design of the scenarios

DNV designed the scenario layouts based on a relatively flat, rectangular piece of land. The following sections describe other factors considered.

3.1.1 Ground cover ratio

DNV determined the ground cover ratio for tracker and fixed tilt systems that would be appropriate for projects in Texas and Spain. The spacing of the fixed tilt rows ensured no interrow shading between the hours of 9 am and 3 pm throughout the year. As module dimensions vary between the studied modules, different row spacings are used for each scenario. DNV did not optimize the tracker layouts for energy production as the primary goal of this analysis is a comparison between module types and their associated balance of system. Row spacing is based purely on what would be reasonable for the area.

3.1.2 Racking material

DNV notes that the thickness and length of racking piles is highly dependent on the specific project site conditions. Therefore, DNV has not calculated the tonnage of material per rack and has instead focused on the total number of piles based on DNV’s experience for each racking type. Further, fixed tilt racking designs can vary greatly in how the support structures are designed, with some utilizing multiple smaller supports as opposed to one larger one. DNV has assumed the larger support option for this analysis.

3.1.3 Racking structure

The length and number of racks was chosen so that the layout of the site was rectangular shaped, with the optimal shape being square. String lengths were also considered so that all strings were within a single row, with no strings being split between rows.

3.1.4 DC combiner boxes

DC combiner boxes were placed strategically throughout the array to minimize the amount of string homerun wiring. The number of strings per combiner box was determined based on typical combiner box ampacity ratings, the project layout, and number of strings per rack.

3.1.5 Module stringing strategy

For modules in portrait orientation, a skip stringing design was used to minimize the length of dc homeruns to the combiner boxes. When modules are laid out in landscape orientation, module leads are not long enough to allow skip stringing, so standard stringing methods were used, resulting in longer module dc homeruns lengths. The number of modules per string was determined based on the maximum voltage of the modules and inverter and for constructability.

3.1.6 Inverter

Inverters were placed within the arrays as is typically seen in utility scale projects in the industry. Depending on the array orientation, access roads may bisect a given inverter's associated modules or a small segment of the array may be carved out for the inverters. A twenty-foot-wide access road was assumed. The model of the inverter chosen for these designs is capable of accepting the various dc capacities in each scenario.

3.1.7 Conductor sizing

Conductor sizes were chosen to limit the maximum voltage drop to less than 2%, limit the average voltage drop to less than 1.5%, and meet necessary ampacity requirements. As the 210 modules have higher currents than the 182 module, a larger dc string conductor size was used for these conductors to keep the dc losses relatively similar to those of the 182 module. DC conductors were assumed to be routed to dc combiner boxes and then buried underground and routed to the inverter location.

4 RESULTS

The tables below list the total equipment necessary for each 3.7 MWdc block design in Texas along with their associated cost per watt.

Table 4-1 Scenario 1 equipment totals and costs

	Parameter	Scenario 1: 1P Tracker		
System Design	Module type	182-72c	210-55c	210-60c
	Array design	(27 modules per string x 3 strings per rack) x 84 racks	(35 modules per string x 2 string per rack)x 98 racks	(32 modules per string x 2 strings per rack) x 98 racks
	DC capacity (MW)	3.67416	3.7387	3.73184
Mounting system	Piles per rack	12	10	11
	Pile spacing (m)	8.1	8.1	8.1
	Total number of piles	1008	980	1078
	Racking Cost (¢/W)	7.27	7.50	7.50
	Piles (¢/W)	2.35	2.29	2.52
Cable and combiner box	PV string cable 2 way length (m)	21,302	14,329	14,850
	PV string cable (#10 AWG Cu PV wire) (¢/W) ($0.86/m)	0.15	-	-
	PV string cable (#8 AWG Cu PV wire) (¢/W) ($1.26/m)	-	0.15	0.13

	Parameter	Scenario 1: 1P Tracker		
	Combiner Box configuration	14 w/ 18 strings	14 w/ 14 strings	14 w/ 14 strings
	Combiner Box (¢/W)	0.43	0.42	0.42
	DC homerun cable 2 way length (m)	1,920	2,270	2,150
	DC homerun cable (750 kcmil Al) (¢/W) ($7.97/m)	0.42	0.48	0.46
AC equipment	Inverter (¢/W)	3.68	3.62	3.63
Land	Inter-row spacing (m)	4.39	4.43	4.21
	Land (m^2)	52,803	54,451	55,950
	Land (¢/W) Note: this represents total 20 year lease payments	2.35	2.42	2.49
	Civil work (¢/W)	6.55	6.76	6.94
Labor	Labor DC (¢/W)	1.58	1.83	1.59
	Labor Module (¢/W)	0.9	0.9	0.9
	Labor Racking (¢/W)	1.7	1.80	1.80
	Labor Foundation (¢/W)	1.79	1.74	1.92
Total BOS	**Totals (¢/W)**	**29.13**	**29.91**	**30.32**

Table 4-2 Scenario 2 equipment totals and costs

	Parameter	Scenario 2: 2P Fixed Rack	
System Design	Module type	182-72c	210-60c
	Array design	(27 modules per string x 8 strings per rack) x 32 racks	(32 modules per string x 6 strings per rack) x 33 racks
	DC capacity (MW)	3.73248	3.76992
Mounting system	Piles per rack	24	24
	Pile spacing (m)	5.1	5.1
	Total number of piles	768	792
	Racking Cost (¢/W)	4.07	4.20
	Piles (¢/W)	1.02	1.06

	Parameter	Scenario 2: 2P Fixed Rack	
Cable and combiner box	PV string cable 2 way length (m)	12,875	8,687
	PV string cable (#10 AWG Cu PV wire) (¢/W) ($0.86/m)	0.09	-
	PV string cable (#8 AWG Cu PV wire) (¢/W) ($1.26/m)	-	0.09
	Combiner Box configuration	16 w/ 16 strings	16 w/ 12 strings, 1 w/ 6 strings
	Combiner Box (¢/W)	0.48	0.51
	DC homerun cable 2 way length (m)	3170	3130
	DC homerun cable (750 kcmil Al) (¢/W) ($7.97/m)	0.68	0.66
AC equipment	Inverter	3.63	3.59
Land	Inter-row spacing	6.10	5.82
	Land (m^2)	38,936	39,415
	Land (¢/W) Note: this represents total 20 year lease payments	1.73	1.75
	Civil work (¢/W)	6.39	6.47
Labor	Labor DC (¢/W)	2.04	1.9
	Labor Module (¢/W)	0.8	0.8
	Labor Racking (¢/W)	1.45	1.50
	Labor Foundation (¢/W)	1.02	1.06
Total BOS	**Totals (¢/W)**	**23.42**	**23.58**

Table 4-3 Scenario 3 equipment totals and costs

	Parameter	Scenario 3: 4L Fixed Rack	
System Design	Module type	182-72c	210-55c
	Array design	(27 modules per string x8 string per rack) x 32 racks	(35 modules per string x 6 strings pre rack) x 33 racks
	DC capacity (MW)	3.73248	3.77685
Mounting system	Piles per rack	24	25
	Pile spacing (m)	5.1	5.1

	Parameter	Scenario 3: 4L Fixed Rack	
	Total number of piles	768	825
	Racking Cost (¢/W)	4.52	4.66
	Piles (¢/W)	1.02	1.10
Cable and combiner box	PV string cable 2 way length (m)	35,113	28,218
	PV string cable (#10 AWG Cu PV wire) (¢/W) ($0.86/m)	0.25	-
	PV string cable (#8 AWG Cu PV wire) (¢/W) ($1.26/m)	-	0.29
	Combiner Box configuration	16 w/ 16 strings	16 w/ 12 strings, 1 w/ 6 strings
	Combiner Box (¢/W)	0.48	0.51
	DC homerun cable 2 way length (m)	3500	3020
	DC homerun cable (750 kcmil Al) (¢/W) ($7.97/m)	0.75	0.64
AC equipment	Inverter	3.63	3.58
Land	Inter-row spacing	6.08	5.88
	Land (m^2)	39,176	40,473
	Land (¢/W) Note: this represents total 20 year lease payments	1.74	1.8
	Civil work (¢/W)	6.43	6.64
Labor	Labor DC (¢/W)	2.26	2.06
	Labor Module (¢/W)	0.8	0.8
	Labor Racking (¢/W)	1.45	1.50
	Labor Foundation (¢/W)	1.02	1.10
Total BOS	**Totals (¢/W)**	**24.35**	**24.69**

Table 4-4 Summary of scenario costs

	Scenario 1: 1P Tracker			Scenario 2: 2P Fixed Tilt		Scenario 3: 4L Fixed Tilt	
Module type	182-72c	210-55c	210-60c	182-72c	210-60c	182-72c	210-55c
Total BOS (¢/W)	**29.13**	**29.91**	**30.32**	**23.42**	**23.58**	**24.35**	**24.69**

4.1 Details of the results

When calculating the differences in costs between each layout and scenario, DNV determined a baseline value to scale the associated costs by averaging the totals for that particular parameter. In some instances, averages were calculated based on the racking technology (fixed vs tracking) as certain aspects should not be compared across all scenarios.

4.1.1 Labor

DC labor entails the work needed to trench, install all cabling, and install combiner boxes. Module labor is the work needed to install modules on the tracker system. Racking labor is the work to install the racking components aside from the piles, which is covered in the foundation labor costs.

4.1.2 Civil work

This includes the costs of grading the land, water flow and flood plain management, and roads within the arrays. It is dependent on the size of the land used by the project.

5 SUMMARY

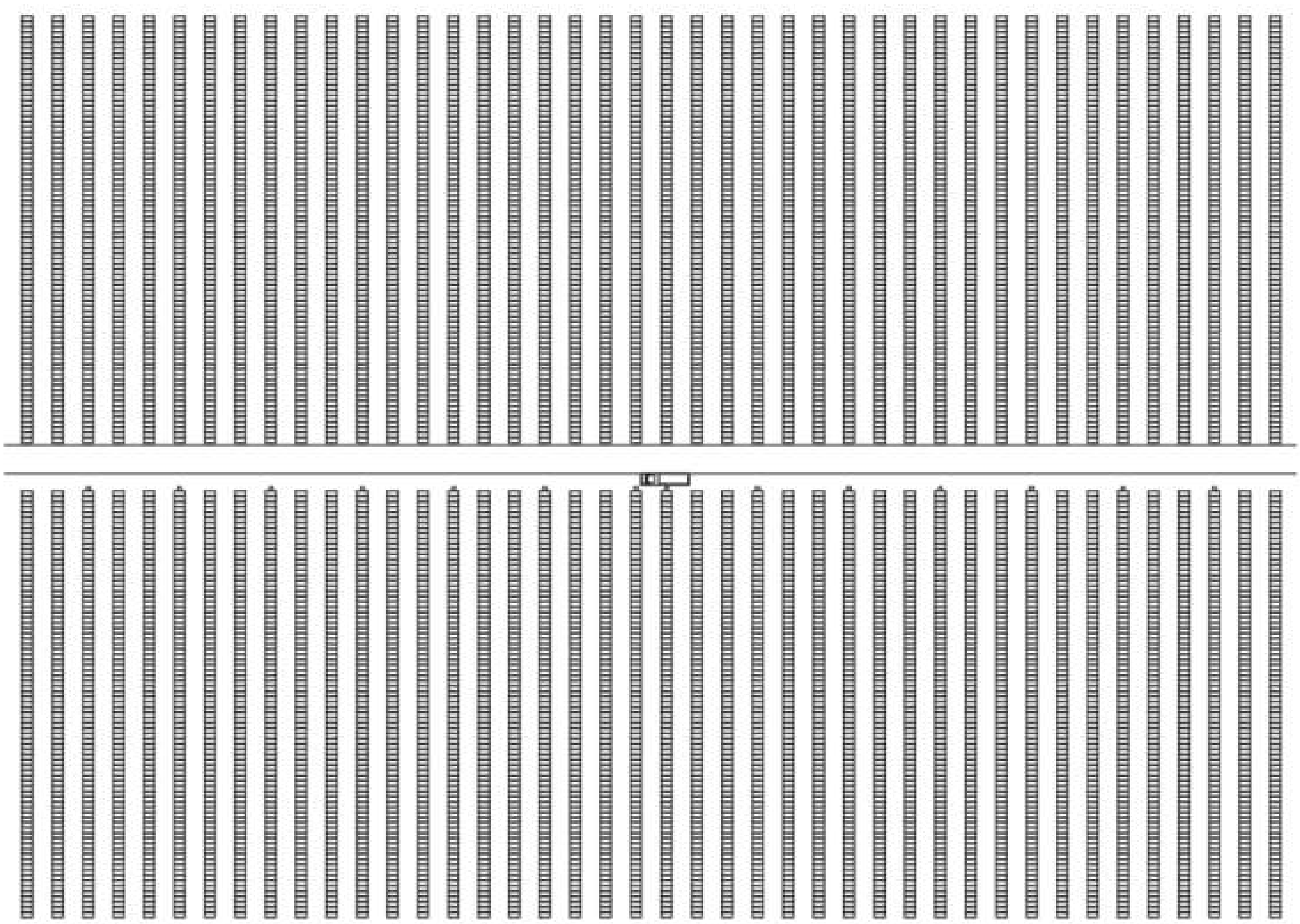
DNV determined the balance of system costs for three different scenarios in Texas utilizing industry data, equipment manufacturer quotes, and DNV's experience. Layouts of each scenario were designed to find the total amount of equipment needed for an approximately 3.7 MWdc block of modules. Results of the analysis show the differences in costs between various design parameters. There is little variation in overall prices within each scenario, meaning the module choice has little effect, but it can be seen that certain racking configurations lead to different overall prices. The variation in two string versus three string trackers also produces a noticeable cost difference. DNV notes that the results should only be used as a comparison between different design choices and are not meant to be indicative of the total costs to build a project. The calculated costs are not inclusive of any work done on the ac electrical side of the project.

6 REFERENCES

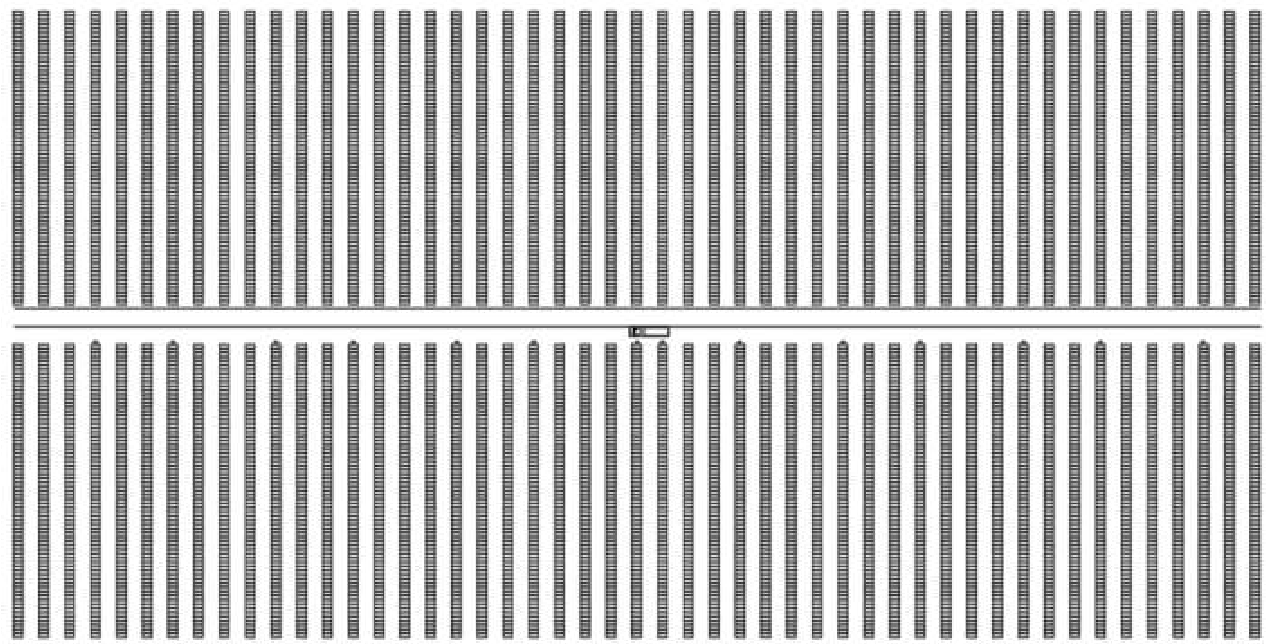
[1] Cox, Molly, Wood Mackenzie's Interactive US Solar PV System Cost Model- H2 2020

APPENDIX A – SCENARIO LAYOUTS

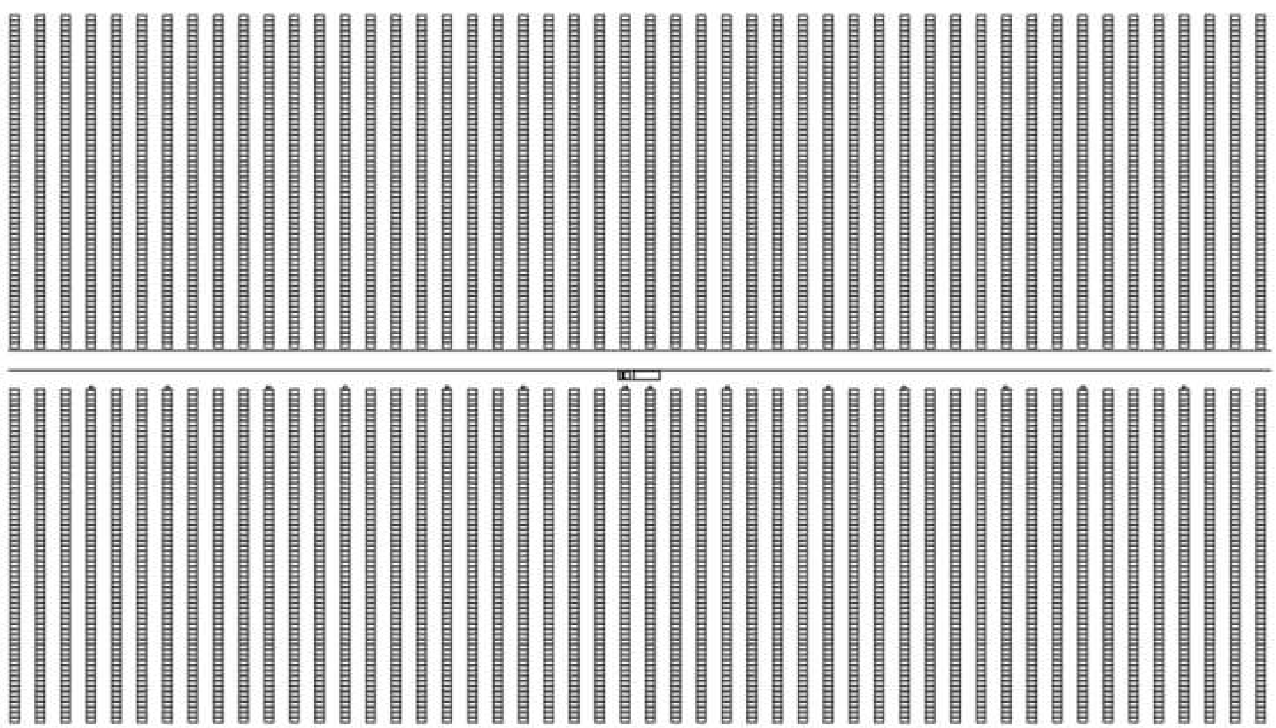
A.1 Scenario 1: 182-72c 1P Tracker



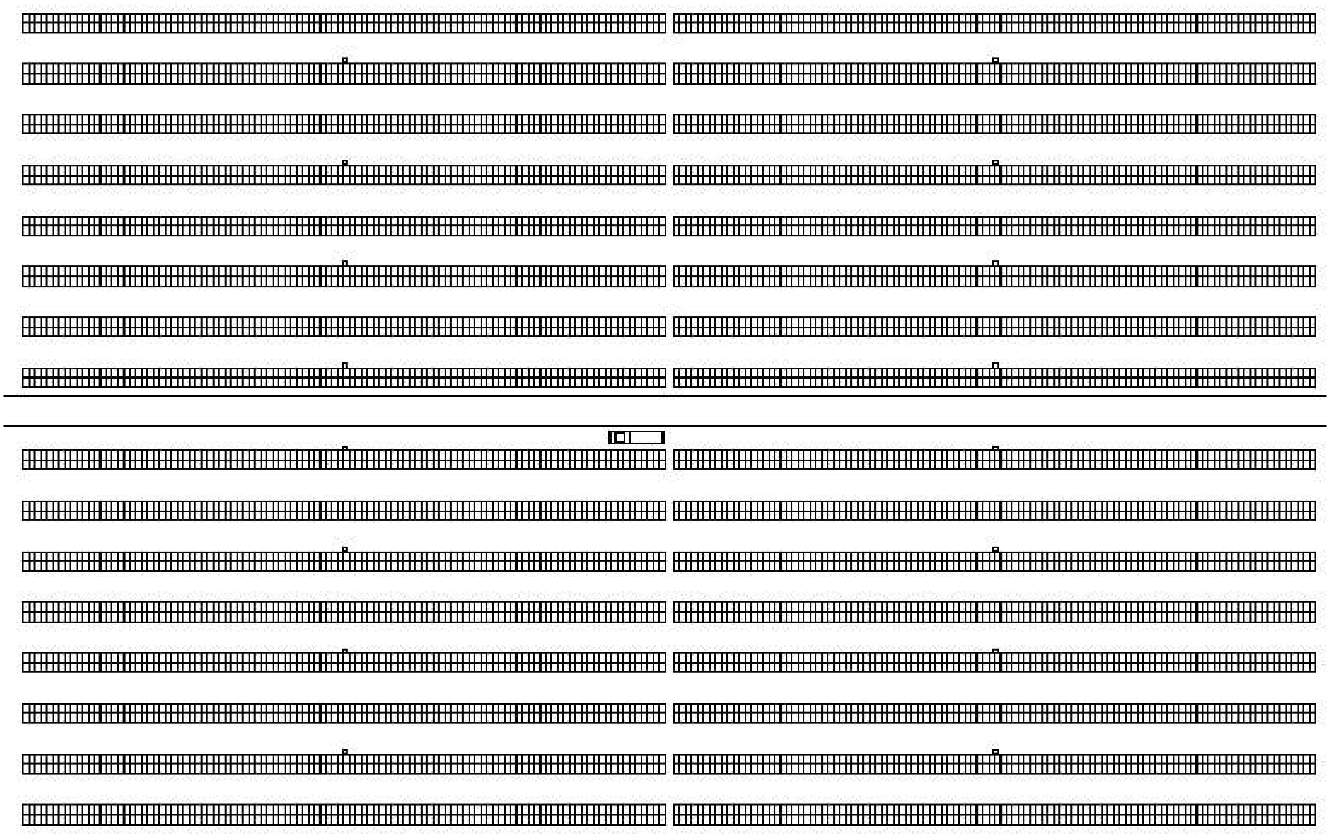
A.2 Scenario 1: 210-55c 1P Tracker



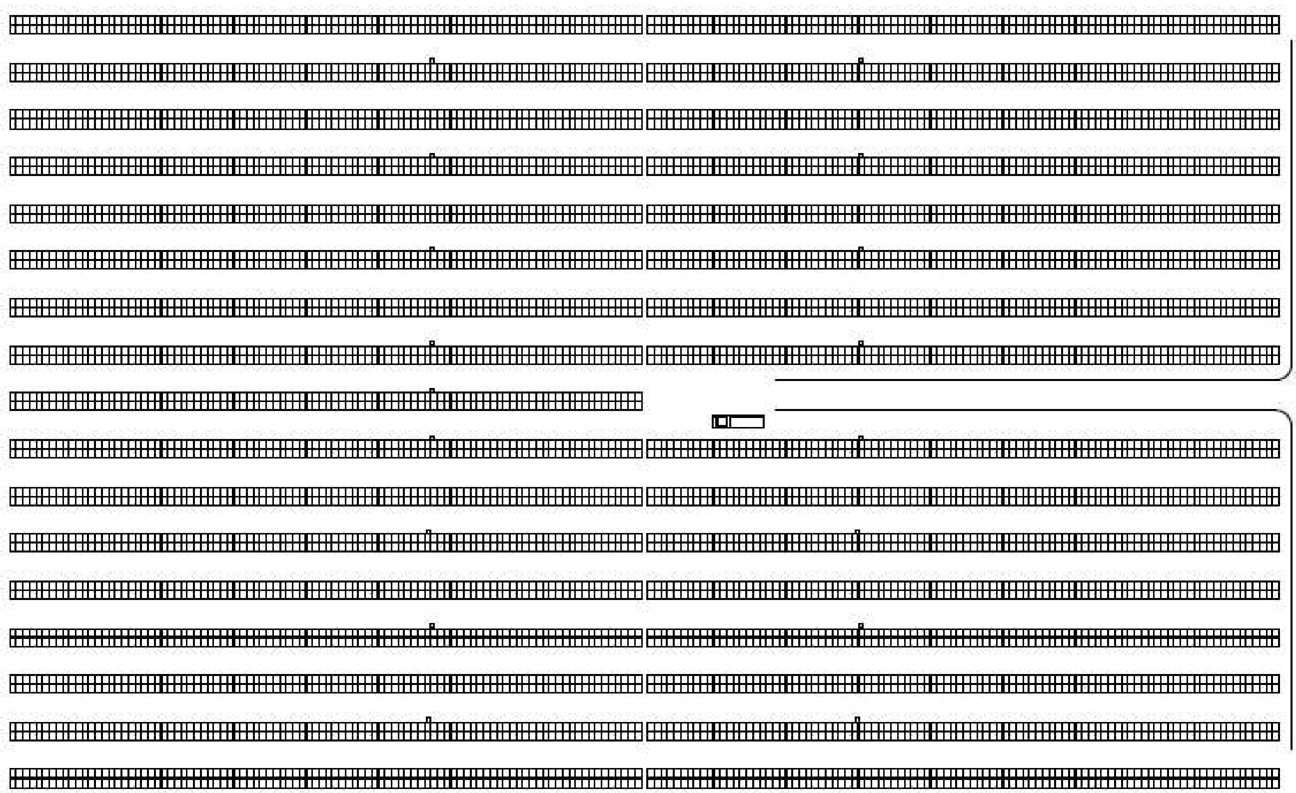
A.3 Scenario 1: 210-60c 1P Tracker



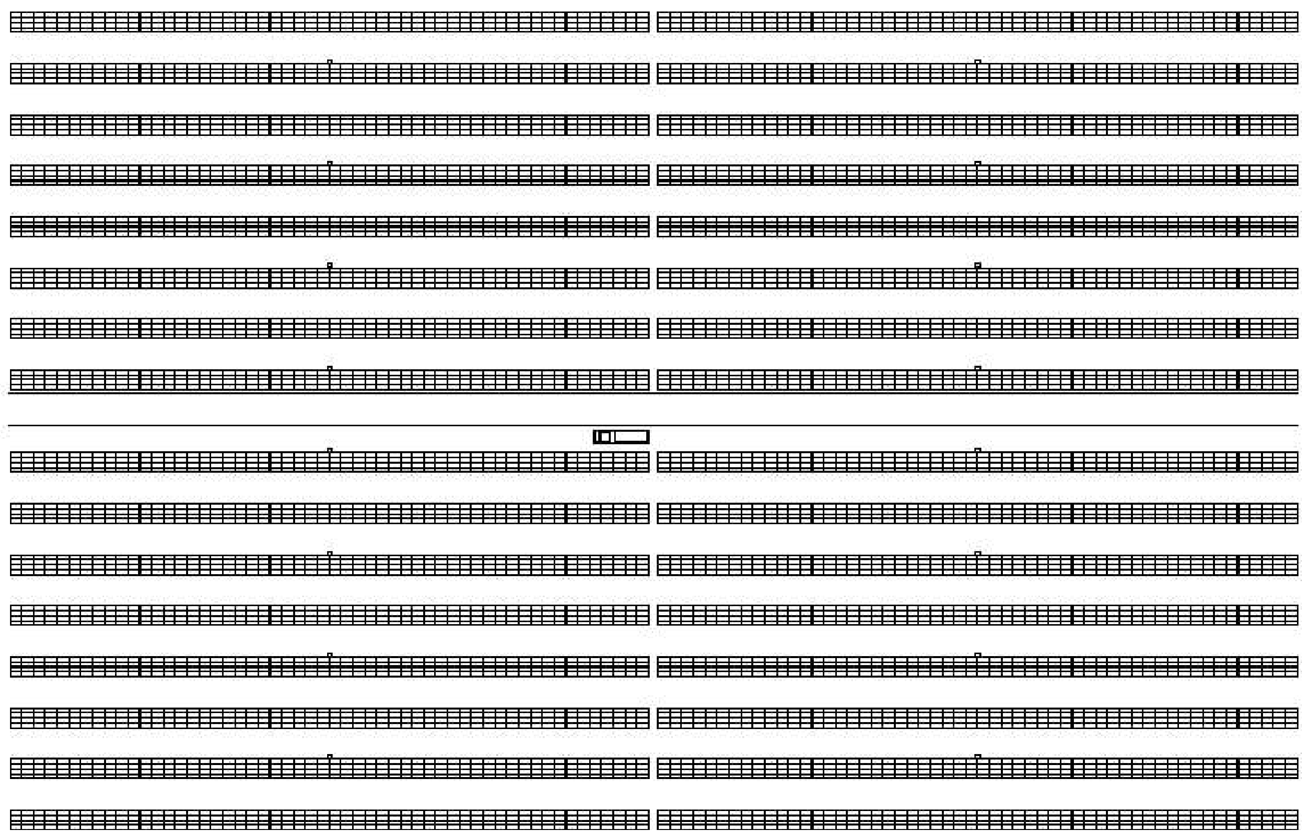
A.4 Scenario 2: 182-72c 2P Fixed



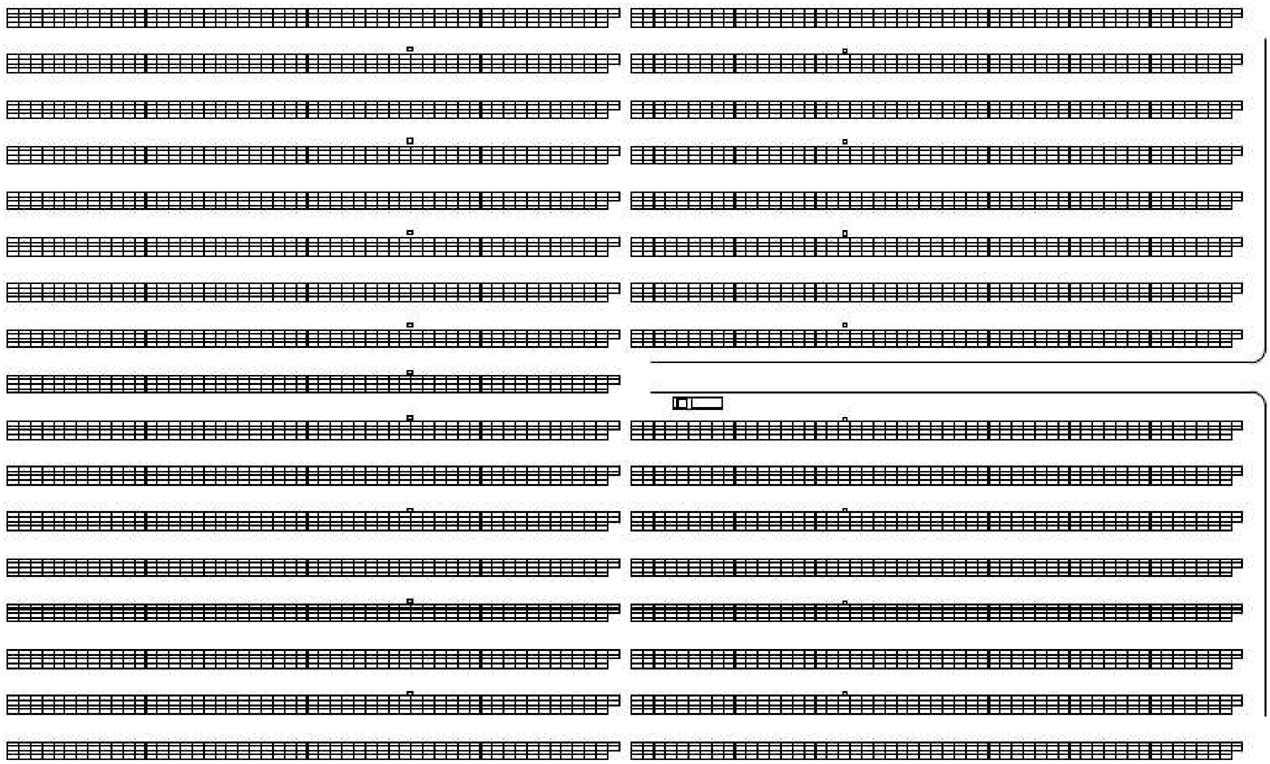
A.5 Scenario 2: 210-60c 2P Fixed



A.6 Scenario 3: 182-72c 4L Fixed



A.7 Scenario 3: 210-55c 4L Fixed



About DNV

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