

Massachusetts Institute of Technology Manufacturing Science/Engineering of Solar Cells

Assignment – Hypothesis Testing of New Wafer Suppliers

Your Manufacturing Engineering team is evaluating multiple second-source silicon wafer suppliers in order to diversify Virtual Solar Inc.’s wafer supply chain. Having multiple qualified suppliers both de-risks potential supply-and-logistics issues and puts pressure on our suppliers to lower their prices. Eight new suppliers are under consideration – of principle concern are (1) wafer price, (2) wafer power performance, and ultimately, (3) \$/watt cost changes in the product. Of course, each supplier promises better cost, performance, quality, reliability, yield ...

Pricing data is provided courtesy of VSI’s Purchasing Department, which has been in preliminary negotiation with each supplier. Purchasing also acquired evaluation samples from each of the new wafer suppliers – 2000 wafers, which is enough to process 20 “lots” of 100 wafers in the fab. The table below summarizes the preliminary pricing data for each supplier.

Ops	Trusted Wafer Co.	Baseline Wafer	\$207.99 / 100 pcs
Line 1	Virtuawafer Pty.	A	\$208.00 / 100 pcs
Line 2	Premium Wafer Inc.	B	\$214.81 / 100 pcs
Line 3	Si4U Pty.	C	\$206.01 / 100 pcs
Line 4	Discount Wafer Co.	D	\$201.23 / 100 pcs
Line 5	Not Silicone Inc.	E	\$205.62 / 100 pcs
Line 6	Acme Co.	F	\$209.99 / 100 pcs
Line 7	Sunpun Solar Gmbh.	G	\$214.27 / 100 pcs
Line 8	Ace Co.	H	\$214.48 / 100 pcs

Your team will evaluate one wafer type on your production line, and we will compare notes between teams as a class. To complete the evaluation, your team needs power performance data. However, with only a limited supply of evaluation wafers, “luck of the draw” and “common cause variance” will surely introduce uncertainty into your evaluation. So, you will use a statistical hypothesis test approach to quantify and communicate this uncertainty. In particular, your team will use a “Two-tailed, 95% Confidence, Hypothesized Mean, Z-hypothesis Test About Lot-Mean Maximum Power (Pmp).” This type of test has been stipulated by the Director of Manufacturing Engineering. Her rationale is

Test Consideration	Design	Rational	Associated Info
Two-tailed		We care <i>both</i> about detecting higher <i>and</i> lower power performance in the evaluation	$Z_{crit} = 1.960$
95% Confidence		The FMEA lists contains no potential risks with Severity/Consequence greater than 7	$C = 95\%$ $\alpha = 0.05$
Hypothesized Mean		Manufacturing Operations has a very precise estimate of the mean power performance of Trusted Wafer Co. wafers (from multiple months of solar production data)	$\mu_0 = 2.4772337$ (watts)
Z-hypothesis Test		Manufacturing Operations also has a very precise estimate of the standard deviation of power performance of Trusted Wafer Co wafers.	$\sigma_0 = 0.017852534$ (watts)
Lot-Mean Maximum Power (Pmp)		Lot-mean data are Normally distributed and are not auto-correlated, two necessary conditions for hypothesis tests. (Individual wafer data are non-Normal and highly auto-correlated.)	Query Output Params: “Lot-level Data” “Mean” “PmP”

Assignment Objectives:

1. Use the VMES **Engineering > Data Query and Export** feature to query lot-mean Pmp data from 4 initial engineering lots pertaining to your assigned wafer type (type A-H). These lots that have already been fabricated by Jeff and are ready for evaluation. See the Helpful Tips section at the end of this handout.
2. Use statistical hypothesis testing to evaluate the data pertaining to your assigned wafer type, against the current baseline (see the table above for baseline data). Start with data from the initial 4 lots already prepared in the VMES. Report your findings (Z_{stat} , p-value and conclusion) to the class.
3. Use the **VMES Engineering > Action Planner > Eng Lots** feature to create 16 additional engineering lots in the VMES. There's an easy shortcut, Jeff will show you in class. When the VMES updates again (around late o'clock in the night), these lots will be fully fabricated and ready for data query and further analysis.
4. Repeat the statistical hypothesis testing to evaluate 20 lots of data. Report your findings (Z_{stat} , p-value and conclusion) to the class.
5. Compute the potential performance cost change (delta \$/watt against the baseline performance cost) for your wafer type.

What to Submit:

1. One report per team, not more than 1 page in length.
2. A concise table of your hypothesis test results for the 4-sample and 20-sample evaluations: Z_{stat} , p-value, conclusion. Be sure to state your conclusion properly (eg. "Fail to Reject with 95% confidence and a p-value of 0.345")
3. Compute the delta in performance cost (\$/watt to the 100th of a cent) compared to the baseline case. Make the best possible estimate from your available data. For example, report a savings as $-\$0.0123/\text{watt}$ and an increase as $+\$0.0098/\text{watt}$.
4. Recommend whether your assigned supplier should be considered as a supplier to Virtual Solar Inc. Make a concise recommendation with support from your data and analyses.
5. Consider the results from the rest of the class. Recommend the best supplier to consider for Virtual Solar Inc. Make a concise recommendation with support from your data and analyses.

Helpful Tips

1. Getting the Virtual Manufacturing Execution System (VMES) Software

- The VMES software is free. Download it from <https://sites.google.com/site/virtualsolarcellsinc/>
- After downloading, run the installer. NB: the software runs well on Windows PC, but may have difficulty on Mac emulators.

2. Logging Into the Virtual Cell Factory (VCF) using the VMES Software

- The Virtual Cell Factory is in the cloud, you access it using the VMES software.
- Select **Account > Login** and enter your team's Login Name and Password. Login Name and Password are the same for the MIT class, depending on your assigned line number ("mitline1"/"mitline1", "mitline2"/"mitline2", etc).
- Click Connect, then Select, then Login (your class VCF is "University/MIT VCF 2013").

3. Setting up a Query

- Select **Engineering>Data Query and Export**, and then fill up the appropriate query parameters on the form. See the illustration below.
- Click the Query button. From the resulting table, you can use ctrl-c to copy the pertinent data.

Engineering Data Query Export

Select by Line/Step:
Line: Your line here
Step: FGI

Select by Lot Property:
 Production Lots
 Engineering Lots
 In WIP Buffer
 In Process

Type of Output Data:
 Wafer-level Data
 Lot-level Data
 Mean
 Median
 Std Dev

Output Parameters:
 All
 Isc
 Voc
 Imp
 Vmp
 Pmp
 EF
 FF
 Rshunt
 Rseries

Select By Timestamp:
On or After:
Week: Week 1
Day: Day 1
On or Before:
Week: Week 8
Day: Day 7

Select by Comment Fields:
 LotIdentifier =
WAFER EVAL
 Comment =

Select by Database:
 Current FGI Database
 Archive FGI Database

Query Export Finished

4. Creating 16 additional engineering lots

- Select **Engineering>Action Plan>Eng Lots**, and then select one of the previously completed engineering lots by right clicking on the row header at the left-most position of the Eng Lot table.
- Right click again and select Duplicate Multiple.
- Enter 16 and click ok.
- This will create 16 duplicate engineering lots, all highlighted in red with a Status of "New"

NB: ONLY ONE PERSON SHOULD ENTER THE DUPLIATES, TO AVOID UNNEEDED DUPLICATES!!!!

Edit Engineering Action Plan

Eng Lots

EngID	APTyp	Wk	Fal	Lir	Str	LotIdentifier	Comment	Starts	HoursF	HoursC	IsSplit	IsHold	Status	RunCo
902	Eng	2	2	1	1	WAFER EVAL	Wafer C1	100	1	0	1		New	Edit
678...	Eng	2	2	6	10	TEXTETCH T2	8.75	100	1	1	0		FGI	Edit
10c3...	Eng	2	2	3	10	TEXTETCH T2	7.75	100	1	1	0		FGI	Edit
d3d...	Eng	2	2	4	10	TEXTETCH T2	8.00	100	1	1	0		FGI	Edit
8cc9...	Eng	2	2	6	10	TEXTETCH T2	8.00	100	1	1	0		FGI	Edit
a5h6...	Eng	2	2	5	10	TEXTETCH T2	8.00	100	1	1	0		FGI	Edit
cae2...	Eng	2	2	6	10	TEXTETCH T2	8.00	100	1	1	0		FGI	Edit
06h8...	Eng	2	2	4	10	TEXTETCH T2	8.25	100	1	1	0		FGI	Edit
bb6...	Eng	2	2	3	10	TEXTETCH T2	8.00	100	1	1	0		FGI	Edit
1de...	Eng	2	2	1	10	TEXTETCH T2	7.25	100	1	1	0		FGI	Edit

Total Hours Planned: 249.00
Total Hours Executed: 248.00
Total Hours Remaining: 0.00

OK Cancel

Right click here first to select an engineering lot

Right click here a second time and select "Duplicate Multiple"

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