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BEFORE THE PUBLIC SERVICE COMMISSION OF UTAH

In the Matter of the Application of Rocky Mountain Power to Establish Export Credits for Customer Generated Electricity	**DOCKET NO. 17-035-61** **Vivint Solar Exhibit 1 – Phase 1**

DIRECT TESTIMONY OF CHRISTOPHER WORLEY
FOR VIVINT SOLAR, INC.

March 22, 2018

I. INTRODUCTION

Q.   Please state your name, business address and position with Vivint Solar.

A.   My name is Christopher Worley. My business address is 1800 W. Ashton Blvd, Lehi, Utah 84043. I am Director of Rate Design with Vivint Solar.

Q.   Please describe your education and professional experience.

A.   I have a Bachelor's Degree in English from the University of Colorado at Denver, and a Master's Degree and Doctorate in Mineral and Energy Economics from the Colorado School of Mines. I have been with Vivint Solar for five months. Before joining Vivint Solar, I was the Director of Policy and Research for the Colorado Energy Office, where I led legislative and regulatory efforts, including testifying before the Colorado Public Utilities Commission.

II. SUMMARY AND RECOMMENDATIONS

Q.   What is the purpose of your testimony?

A.   My testimony provides the Commission with recommendations on the load research part of the export credit proceeding. Specifically, I identify deficiencies in Rocky Mountain Power's ("RMP" or "the Company") load research methodology and provide recommendations to improve it.

Q.   What are your recommendations for the Commission?

A.   I recommend (1) increasing the sample of customers participating in the study to increase the accuracy of the study, (2) using simple sampling instead of stratified sampling, (3) sampling based on RMP's distribution system topology rather than county-level sampling, and (4) collecting generation, load, and export data from study participants rather than generation from some and load and export data from others. Also, I provide recommendations on how to increase the sample at a lower cost than RMP's estimate for installing meters. It is vital that the load

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25   research study collect enough data (a large enough sample) in Phase I to ensure parties can

26   estimate costs and benefits in Phase II.

27   Finally, I have additional recommendations should the Commission choose stratified

28   sampling instead of simple sampling. Under that methodology, I recommend (1) stratifying on

29   gross consumption rather than on system capacity and (2) separately analyzing residential and

30   commercial customers.

31

32   **III.   BACKGROUND**

33   **Q.   What is the purpose of the export credit proceeding?**

34   A.   This proceeding was initiated as a result of the settlement stipulation in Docket 14-035-

35   114. The Commission ordered that this proceeding "investigate the costs and benefits of the

36   Company's net metering program."[1] Based on the cost benefit analysis, "the Commission will

37   determine a just and reasonable rate for export credits for customer generated electricity."[2]

38   This proceeding gives the Commission an opportunity to better understand the impact,

39   both costs and benefits, of DG on RMP's distribution system. It is an opportunity for the

40   Commission to put hard numbers on how RMP's system operates and should inform how, where,

41   and when RMP invests in its distribution system in the future. This proceeding has the potential

42   of influencing hundreds of millions of dollars of customer and utility investment by answering

43   critical questions. Questions like: Could system orientation (azimuth) help reduce RMP's peak

44   demands, and therefore save money for RMP ratepayers? Does distributed generation over-tax

45   distribution assets or does it reduce the need for using transmission assets? What impact does

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[1] Direct Testimony of Kenneth Lee Elder Jr, page 2
[2] Settlement Stipulation, page 10

46   distributed generation have on air quality along the Wasatch Front? These are the types of

47   questions that parties and the Commission should be asking and answering in this proceeding.

48   Q.   **What is the purpose of the load research study?**

49   A.   According to RMP, "[l]oad research gathers the data needed to study customer usage so

50   the Company can effectively allocate costs, design rates, plan for load, appropriately size

51   transformers and distribution circuits, and enhance customer service."[3] But more than just a

52   simple process to estimate generation at customer-sited systems, this step of the proceeding is

53   critical in ensuring the data needs of the study. As noted in the Commission's order on the

54   settlement stipulation, parties have the burden to prove cost and benefit estimation.[4] Care must

55   be taken in Phase I to ensure the research methodology is structured to allow costs and benefits

56   to be estimated in Phase II of the proceeding. There is no way to retroactively fix suboptimal

57   methodology two years from now during Phase II of the proceeding.

58   Q.   **Is the Company's proposed methodology sufficient to achieve the purpose of the**

59   **load research study?**

60   A.   No. Unfortunately, the Company's methodology is likely to result in biased estimates that

61   lack sufficient statistical power. Stratifying based on system capacity ignores DG system

62   orientation, tilt, and shading, factors that have a strong impact on system production.

63   Additionally, the Company is proposing to collect load and export data from one set of

64   customers and generation data from another.[5] Moreover, given the small sample, the study would

65   be fragile to unforeseen problems. If for any reason data are not collected from a small set of

66   study participants, the study results could be wrong. Finally, such a small sample may lack

[3] Direct Testimony of Kenneth Lee Elder Jr, page 3.
[4] Docket No. 14-035-114, Settlement Stipulation, page 10.
[5] Direct Testimony of Kenneth Lee Elder Jr, page 6.

67 statistical power for estimating costs and benefits. For example, there may be avoided

68 transmission benefits to DG solar, but the estimated benefits may not be statistically significant

69 due to a small sample. This is the same problem parties had in Docket 14-035-114. RMP's

70 sample size is too small to produce credible results.

71 **Q.   Did Vivint Solar expect this load research phase of the proceeding to be**

72 **collaborative?**

73 A.   Yes. The settlement stipulation in Docket 14-035-114 states: "The Company will

74 facilitate a workshop with the Parties and other stakeholders soon after the Export Credit

75 Proceeding is initiated to discuss the type and scope of data expected to be considered in

76 determining the appropriate export rate."[6] The Commission's scheduling order in this phase

77 contemplated the possibility of having no hearing to determine the requirements for RMP's load

78 research study because the parties might be able to reach agreement.

79 **Q.   Did RMP facilitate a workshop?**

80 A.   Yes, but the parties and other stakeholders met together just once to review how RMP

81 proposed to conduct the study. Thereafter, RMP converted the second workshop meeting to a

82 conference call to announce the minor changes it had accepted for its February 15, 2018 filing.

83 **Q.   What is the upshot?**

84 A.   There is significant disagreement over how RMP should conduct the study and the

85 Commission will have to hear this matter April 17, 2018 to decide the contested issues.

86

87 **IV.   STUDY ACCURACY**

88 **Q.   What level of accuracy does the Company propose?**

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[6] Docket No. 14-035-114, Settlement Stipulation, page 10.

89　A.　The Company proposes accuracy of +/-10% at the 95% confidence level.

90　Q.　**Is that level of accuracy problematic?**

91　A.　Yes. While a 95% confidence level is appropriate, +/-10% is a very wide range for

92　results. For example, the study will likely estimate the amount of exported power during RMP's

93　Peak Hours.[7] Exports during peak hours are likely to be more valuable than exports during off-

94　peak hours. With the Company's proposed level of accuracy, the estimate of Peak Hours exports

95　could be up to 10% too high or 10% too low. That means ratepayers could be overcompensating

96　or undercompensating DG customers by up to 10% for power exported to the grid during peak

97　times.

98　　Furthermore, as stated previously, with such a wide range for the study estimates, the

99　study has low statistical power to estimate costs and benefits. Parties have the burden of proof to

100　estimate costs and benefits. If the data lacks statistical power, parties may be unable to estimate

101　some costs and benefits.

102　Q.　**What recommendations do you have on study accuracy?**

103　A.　I recommend increasing the sample so that the study is accurate to at least +/-5% at a

104　95% confidence level.

105

106　V.　**DATA COLLECTION**

107　Q.　**How does the Company propose to collect data?**

108　A.　According to the discussion at the workshop, RMP plans on collecting generation data by

109　installing large revenue-grade meters on customer homes and facilities. RMP described revenue-

110　grade meters as large boxes, perhaps the size of a large residential breaker box. One of these

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[7] Utah Time of Day Peak Hours are 1:00 PM to 8:00 PM Monday through Friday during the months of May through September https://www.rockymountainpower.net/ya/po/otou/utah/ph.html

111 large meters will need to be installed on the home or business of each study participant. Given

112 the cost and the large, obtrusive size, the Company has expressed a desire to limit the number of

113 meters to limit the number of customers that are inconvenienced.

114 **A. METERS AND DATA ACCESS**

115 **Q.   Are there problems with RMP's proposed data collection?**

116 A.   Yes. There are two main problems: the Company's description of revenue-grade meters

117 and the inconsistent data collection from study participants.

118 **Q.   Are there other hardware-based options for data collection?**

119 A.   After doing a brief Google search, I found two small revenue-grade meters that seem

120 much less obtrusive than what the Company described. For example, the Locus Energy LGate

121 120 is the size of a normal residential electricity meter, collects data at 5 minute intervals and is

122 accurate to the 0.2% level (certified ANSI C12.20).[8] The LGate 120 is available for $299 with

123 free shipping from Amazon.com, including five years of cell service for data collection.[9] I also

124 found the Solar-Log 350, which is available from the Alt E store for $649.[10] Like the LGate 120,

125 the Solar-Log 350 is the size of a residential electricity meter, has revenue-grade accuracy of +/-

126 0.2%, and comes with a five-year cell plan. These are just two examples that I found of meters

127 that are roughly the size of a coffee can. There are likely more companies that sell similar solar

128 monitoring systems smaller than the large meters described by RMP.

129 **Q.   What about installation of these meters?**

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[8] https://www.locusenergy.com/solutions/residential Accessed March 21, 2018.
[9] "Locus Energy LGate120 LGate 120 5 Year Monitoring" https://www.amazon.com/Locus-Energy-LGate120-LGate-Monitoring/dp/B06XB46VGJ/ Accessed March 21, 2018.
[10] "Solar-Log 350 & GE Revenue Grade Meter/Datalogger" https://www.altestore.com/store/meters-communications-site-analysis/solar-monitoring-systems/solar-log-350-ge-revenue-grade-meterdatalogger-p11759/ Accessed March 21, 2018.

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130   A.   Based on our installer estimates, it should take an electrician no more than four hours to

131   install a meter similar to the LGate 120 or the Solar-Log 350.

132   Q.   **Are there software alternatives for data collection that would not require installing**

133   **a new meter?**

134   A.   Yes. Solar installers monitor production data from systems using cellular or Wi-Fi

135   connections. While production data is owned by customers, RMP could request customers

136   disclose their production data. Once a customer has signed a disclosure form, the solar installer

137   could give that data to RMP. Many customers might choose to participate in the study through

138   production data because it avoids the installation of a separate meter.

139   Q.   **How accurate is the data from inverters?**

140   A.   Typically, data from inverters is accurate to +/- 5%.

141   Q.   **Would that level of accuracy be a problem for the study?**

142   A.   No. Data from inverters is less accurate than the revenue-grade meters, but the study is

143   only accurate to +/-10%. So inverter data accurate to +/-5% won't reduce the accuracy of the

144   study. To be clear, using revenue-grade meters accurate to +/-0.2% will not increase the accuracy

145   of the study.

146   **B. STUDY DATA**

147   Q.   **What data does the Company propose collecting?**

148   A.   The Company proposes collecting exported energy from transition program customers,

149   delivered energy from transition program customers, and DG system production from

150   grandfathered net energy metering ("NEM") customers.[11]

151   Q.   **Are there problems with this approach?**

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[11] Direct Testimony of Kenneth Lee Elder Jr, page 6.

152   A.   Yes. By collecting load and export data from one set of customers, and generation data

153   from another set, the analysis compares average data rather than tracking the performance of DG

154   systems. This is problematic. Using this approach, parties will not be able to estimate the direct

155   impact of DG on RMP's distribution system.

156   C. DATA COLLECTION RECOMMENDATIONS

157   Q.   **What process do you recommend for the Company to follow for sampling and data**

158   **collection?**

159   A.   The Company should collect delivered energy, exported energy and DG system

160   production from each customer participating in the study. RMP should select a suitably large

161   pool of potential study participants. I recommend a sample size large enough to ensure the

162   number of actual study participants enables accuracy of +/-5% at the 95% confidence level. Of

163   the pool of potential study participants, RMP should randomly select a number of customers to

164   install meters, either the large, expensive revenue-grade meters RMP described at the workshop

165   or smaller, cheaper meters like the Locus Energy or Solar-Log. For the remaining customers in

166   the pool of potential participants, RMP should request participation in the study and obtain

167   consent to work with their installer to collect production data. The pool of potential study

168   participants should be sufficiently large to ensure a large enough sample if some customers

169   decline to participate in the study.

170   Q.   **What are the benefits of this approach?**

171   A.   This would allow RMP to collect some data from customer meters but increase the

172   sample without the added cost of installing meters. Data from customer inverters can increase the

173   sample, increasing the accuracy of the study at a lower cost than installing meters.

174   VI.   **SAMPLING**

175   Q.   **How does the Company propose to sample DG customers?**

176   A.   The Company proposes using stratified random sampling, separating solar customers into

177   four bins based on system capacity: less than 6 kW, 6 to 12 kW, 12 to 80 kW, and greater than

178   80 kW. The Company notes that stratified sampling can increase the statistical precision and

179   reduce sampling requirements.[12]

180   **A. STRATIFIED SAMPLING**

181   **Q.   Are there problems with the proposed stratification?**

182   A.   Yes. There are two main problems with RMP's proposed stratification. Firstly, while

183   stratified sampling reduces the sampling requirements, decreasing the sample may make

184   statistical testing difficult in Phase II of this proceeding. The second problem occurs with the

185   stratification variable. Using system size as the stratification variable ignores important factors

186   that greatly impact system generation, including azimuth (orientation), tilt, and shading from

187   surrounding trees and structures.

188   **Q.   How will a small sample make statistical testing difficult in Phase II?**

189   A.   Parties have the burden of proof estimating costs and benefits of distributed generation. If

190   the sample is too small, it may be difficult or impossible for parties to estimate costs and

191   benefits. For example, let's assume that West-facing systems provide more exported power

192   during peak times. If a party wanted to estimate the impact of West-facing systems during peak

193   times, the sample would need enough West-facing systems for the estimated impact to

194   demonstrate statistical significance. If the sample is too small, there may not be enough statistical

195   power to test that question. Either the model would show no difference between West-facing

196   systems and systems facing other directions, or the relationship would be too weak for the

197   estimate to be statistically significant.

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[12] Direct Testimony of Kenneth Lee Elder Jr, page 4

198 **Q.   Why is stratifying on system capacity problematic?**

199 A.   While system capacity is likely to be correlated with system output, a number of other

200 factors impact system generation, like orientation, tilt, and shading. Ignoring these other factors

201 will bias the results from a stratified sample. To demonstrate this, I used PVWatts to simulate the

202 difference in total generation and hours of peak generation for a 10 kW system with different

203 orientations. Developed by the National Renewable Energy Laboratory, PVWatts is an online

204 tool that estimates energy production of solar at a specific location based on DG system

205 characteristics.[13] Using the standard PVWatts inputs[14], a 10 kW system located at 1407 W North

206 Temple, Salt Lake City, UT 84116 will have different estimated annual production depending on

207 whether the system faces East, South, or West.

208

	AC Output (kWh) by System Azimuth		
	East	South	West
Jan	503	725	516
Feb	678	911	672
Mar	1,013	1,217	985
Apr	1,241	1,355	1,212
May	1,642	1,672	1,532
Jun	1,588	1,600	1,565
Jul	1,649	1,676	1,597
Aug	1,503	1,623	1,464
Sep	1,181	1,395	1,154
Oct	898	1,188	884
Nov	557	803	552
Dec	413	597	415
Total Annual	12,866	14,764	12,550
%Δ from South	-13%		-15%

209 Table 1: Total annual output (kWh) by system azimuth

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[13] "PVWatts Calculator" http://pvwatts.nrel.gov/pvwatts.php Accessed March 21, 2018.
[14] Standard (crystalline Silicon) with 15% efficiency, fixed (roof mount) system, 14% system losses, and 20 degrees tilt

210   As shown in Table 1, total generation is maximized when the system faces South (14,764 kWh).

211   East facing systems generate 13% less and West facing systems generate 15% less than South

212   facing systems.

213   **Q.   What is the impact of system orientation on generation during peak hours?**

214   A.   The impact of system orientation on peak hours generation is even more dramatic. East

215   facing systems produce 32% less and West facing systems produce 20% more than a South

216   facing system baseline (see Table 2). This demonstrates that confounding factors, like system

217   orientation, can greatly impact system generation. Stratifying on system capacity ignores

218   confounding variables that greatly impact the level of generation, which will likely bias the

219   study.

	Peak hours AC Output (kWh) by System Azimuth		
	East	South	West
1:00 PM	555	682	656
2:00 PM	446	605	632
3:00 PM	309	485	563
4:00 PM	171	333	451
5:00 PM	75	181	323
6:00 PM	32	50	161
7:00 PM	6	6	32
8:00 PM	-	-	-
Total Summer	1,593	2,343	2,817
%Δ from South	-32%	-	20%

220

221   Table 2: Summer peak hour output (kWh) by system azimuth

222   **Q.   Why is this a problem? If properly sampled, shouldn't variation in system**

223   **orientation be averaged out?**

224   A.   Properly sampling should address this problem, however the sample size proposed by

225   RMP is not large enough to adequately account for variation in installed DG systems. For

226   example, RMP categorizes 10 kW systems in Strata 2, which covers more than 9,300 systems

11

227   sized 6 kW to 12 kW. The Company proposes sampling only 10 systems to characterize more

228   than 9,300 systems.[15] Such a small sample may or may not be representative of the average

229   system characteristics of the population. Generally, installers will try to install residential rooftop

230   systems facing South (azimuth = 180°) since that orientation will maximize energy production,

231   and therefore provide the quickest payback on the customer's investment. While not every

232   system can be oriented South due to house orientation and roof shape, we should expect that on

233   average systems will be oriented South. But given the small sample, it is possible the sampled

234   systems may disproportionately contain West facing systems or East facing systems. Or some of

235   the sampled systems may be shaded by trees or structures, disproportionately from the

236   population of systems.

237   **Q.**   **How can the issue of disproportionate sampling be addressed?**

238   A.   Increasing the sample will address this issue, averaging out confounding factors.

239   **B. GEOGRAPHIC SAMPLING**

240   **Q.**   **How does the Company propose to ensure the sample is geographically**

241   **representative to the RMP system?**

242   A.   The Company proposes county-level sampling based on the number of customers in each

243   county.[16]

244   **Q.**   **Are there problems with this approach?**

245   A.   Yes. While sampling by county may represent the spatial distribution of DG throughout

246   the state, it may not represent how exported power from DG performs on RMP's distribution

247   system. The sampled systems may or may not be on the same distribution circuit. The cost on

248   distribution circuits with many DG systems may be larger than the cost on distribution circuits

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[15] Direct Testimony of Kenneth Lee Elder Jr, Exhibit RMP___(KLE-1) Page 4 of 4, Table 1
[16] Direct Testimony of Kenneth Lee Elder Jr, Exhibit RMP___(KLE-1) Page 4 of 4, Table 2

249 with only a few DG systems. The purpose of this proceeding is to estimate the costs and benefits

250 on RMP's system. If the load research study doesn't sample according to system topology, then

251 parties cannot assess the true costs on RMP's system.

252 **C. SAMPLING RECOMMENDATIONS**

253 **Q.   How would you recommend RMP sample and collect data from customers?**

254 A.   RMP should select a suitably large pool of potential study participants. I recommend a

255 sample size large enough to ensure the number of actual study participants enables accuracy of

256 +/-5% at the 95% confidence level. Using simple sampling at the +/-5% at the 95% confidence

257 level would require a sample of 379. Using stratified sampling would require a sample of 179 to

258 achieve accuracy of +/-5% at the 95% confidence level.[17]

259   Of the pool of potential study participants, RMP should randomly select a number of

260 customers to install meters, either the large, expensive revenue-grade meters RMP described at

261 the workshop or smaller, cheaper meters like the Locus Energy or Solar-Log. The remaining

262 customers in the pool of potential participants would provide inverter data from the installer.

263   Next, RMP should obtain customer consent, either to install a meter or to request data

264 from installers. The pool of selected customers should be sufficiently large to ensure a large

265 enough sample if some customers decline to opt-in to the study.

266 **Q.   What sampling technique do you recommend the study use?**

267 A.   I recommend using simple sampling, not stratified sampling, to ensure the sample is large

268 enough to estimate costs and benefits in Phase II of the proceeding.

269 **Q.   What if the Commission declines to approve simple sampling, instead using**

270 **stratified sampling as proposed by RMP?**

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[17] RMP Response to Workshop Data Request 4

271   A.   In that case, I recommend stratifying on gross consumption rather than on system

272   capacity. As mentioned above, strata based on system capacity ignore a number of confounding

273   variables, like system orientation, tilt, and shading.

274   **Q.   How can the Company stratify on gross consumption if they do not know what**

275   **customers will consume prior to the study?**

276   A.   RMP could use historical gross consumption for customers that installed solar in 2017.

277   **Q.   Do you have any other recommendations for stratified sampling?**

278   A.   Yes. Additionally, given differing consumption profiles of residential and commercial

279   customers, it would be appropriate to analyze residential and commercial customers separately.

280   **Q.   What recommendations do you have on the geographic stratification?**

281   A.   RMP should sample DG systems based on distribution system topology. Sampling should

282   ensure a variety of scenarios, including distribution circuits with few DG systems and circuits

283   with many DG systems. Additionally, the load research study should collect 15-minute circuit-

284   level distribution system data to match the customer load, export, and generation data.

285

286   **VII.   CONCLUSION**

287   **Q.   To summarize, what are your recommendations for the Commission?**

288   A.   I recommend (1) increasing the sample to increase the accuracy of the study, (2) using

289   simple sampling instead of stratified sampling, (3) sampling based on RMP's distribution system

290   topology rather than county-level sampling, and (4) using consistent data streams from

291   customers rather than comparing estimated averages. Also, I provided recommendations on how

292   to increase the sample at a lower cost than RMP's estimates, including working with installers to

293   access data from system inverters. It is vital that the load research study collect enough data (a

294   large enough sample) in Phase I to ensure parties can estimate costs and benefits in Phase II.

295   Finally, if the Commission chooses stratified sampling instead of simple sampling, I

296   recommend (1) stratifying on gross consumption rather than system capacity and (2) separating

297   residential and commercial customers.

298   **Q.**   **Does this complete your testimony?**

299   A.   Yes.

/s/Christopher Worley

CERTIFICATE OF SERVICE

I hereby certify that on March 22, 2018, I sent a true and correct copy of the direct testimony of Christopher Worley on behalf of Vivint Solar, Inc. in Docket No. 17-035-61by electronic mail to the following:

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