Smart Phone Application to Compute Annual Solar Production of One Panel of a Plug-and-Play Solar Appliance

Cooperative Research and Development Final Report

CRADA Number: CRD-19-00832

NREL Technical Contact: Nate Blair

NREL is a national laboratory of the U.S. Department of Energy
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Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-7A40-82108
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NOTICE

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Cooperative Research and Development Final Report

Report Date: February 10, 2022

In accordance with Requirements set forth in the terms of the CRADA agreement, this document is the final CRADA report, including a list of Subject Inventions, to be forwarded to the DOE Office of Science and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

Parties to the Agreement: Pursifull Services, LLC d.b.a 1st Step Solar

CRADA number: CRD-19-00832

CRADA Title: Smart Phone Application to Compute Annual Solar Production of One Panel of a Plug-and-Play Solar Appliance

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DOE Program Office:

Office of Energy Efficiency and Renewable Energy (EERE), Solar Energy Technologies Office (SETO)

Joint Work Statement Funding Table showing DOE commitment:

Estimated Costs NREL	NREL Shared Resources
Year 1	$70,000.00
TOTALS	$70,000.00

Executive Summary of CRADA Work:

The primary goal of the project is to develop a smart phone application (App) that will be available in both the Apple App Store and the Android store that displays results from the NREL's photovoltaic application, PVWatts Calculator, an application that estimates the energy production and cost of energy of grid-connected PV energy systems, and that will provide quick-response changes based on the orientation of the smart phone by the end user.

Summary of Research Results:

What follows is the list of Tasks in the CRADA and the response/result for each task by NREL. The tasks below contain both the broad tasks as well as specific functional specifications of the mobile app.

1. Develop smart phone app for both Apple and Android smart phones.

This is the overarching task that effectively encompasses all the other tasks. This task was completed as evidenced by the code base and the various summary graphics in the appendix below and confirmation from the CRADA partner. Note that the current situation has been further detailed at the bottom of this report in the summary section below the specific tasks.

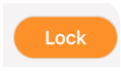
2. Use the latitude and longitude from the internal Global Positioning System (GPS) of the smart phone device to retrieve weather data from the National Solar Radiation Data Base Application (NSRDB API) at https://developer.nrel.gov/docs/solar/nsrdb/nsrdb_data_query/and select the most appropriate data for the device location.

This task was completed and tested. This is evidenced by both the source code as will as you will note the top of Figure 2 (and other Figures below) that the Lat/Long is presented to the user.

3. Allow user to override the smart phone computed zip code with an address (as minimal as the zip code) of their own. This allows use of the app while not present at the target site.

This task was completed and tested. This is evidenced by the screen shot in Figure 8 which demonstrates the result when the user clicks the "Change Location" text on the main screen.

4. A freeze feature allows the user to freeze (hold) values gotten from a specific phone orientation for examination in any phone position. This avoids having to take a screen shot of the app's display in a specific location.

This task was completed and tested. This feature is shown by the button that says "Lock" (

) as shown on the main active page in Figure 4.

5. Use the accelerometer and magnetic field sensor of the smart phone device to provide azimuth and tilt information that will be used in conjunction with weather data to provide inputs to the SAM (System Advisor Model) SSC (SAM Simulation Core) (https://github.com/NREL/ssc) to run the PVWatts calculations.

This task was completed and has been tested in multiple locations and with multiple mobile devices by both the NREL team and the CRADA partner. In fact, this capability is the most unique and notable capability for this device that sets it apart from the web-browser version of the app. The capabilities of this are shown on the results screen in Figure 4.

6. The azimuth (true, not magnetic) and tilt will read out substantially continuously as the phone is moved. It will function while holding the phone in either landscape or portrait mode. While the phone is resting face up on an inclined surface and rotated by hand 360° the annual output will be constant within 3%. Why? Because a panel on an inclined surface with a fixed tilt and azimuth has constant output over any rotation.

Like Task 5 above, this task created a key capability. As you can see in Figure 4, the tilt and azimuth orientation of the phone are both reflected on the active page and are updated continuously as the user moves the phone in their hand.

7. The test for azimuth and tilt is as follows. Lay phone screen up on tabletop. Orient to azimuth of 180°. Keeping long edge of phone on the tabletop, tilt upward every 5° through 95°. The tilt must be within 3°of actual tilt. While tilting, the azimuth will remain unchanged within +- 5°. When tilted between 90°and 95° the display will read 90°. Past 95° the screen goes blank. Repeat this for 12 points of compass. Repeat for tilting with short edge of phone in contact with table.

To make sure that the phone app computes production correctly if tilted on both the long and short edge of phone at the same time. Perform this test. While the phone is resting face up on an inclined surface and rotated by hand 360° the annual output will be constant within 3%. Why? Because a panel on an inclined surface has constant annual output over any rotation.

This test was performed, and the capability verified in both email and meetings with the CRADA partner that it's accurate. Again, the app was tested by multiple people on both the NREL and CRADA partner teams as well as outside users.

8. On a separate page, provide annual and monthly energy production estimates for the nameplate specified by the user together with the GPS and accelerometer data from the iOS device. This requirement is a suggestion from NREL and 1SS readily accepts this because we can see its benefit in making the app have universal appeal. However, we don't want the clutter of the 12-month output on the main screen. The 12-month output will be displayed on a secondary screen.

This task was completed and tested. The monthly results are shown in Figure 7 below with both a graph of monthly data and the table of results.

9. The first screen of the application will display the following.

a) Indications that this is 1SS powered by PVWatts from NREL.
b) A link to the "About" screen which indicates the genesis of the app.
c) Click to use current location or option to overwrite the current location with an address.

This task was completed and tested. Design iterations with the client subsequent to the CRADA SOW changed the format of the initial screen shots in the CRADA document. Figure 2 demonstrates the content of the "About" page in the code which was finally delivered to the CRADA partner.

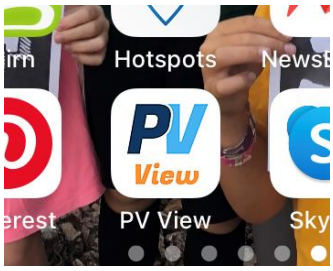
10. On the second screen

a) *PVWatts estimate of residential electricity cost (cents per kWh) round to nearest tenth of cent (can be over-ridden by user)*
b) *Watts per panel (default value 380 W) round to nearest 5 W (can be over-ridden byuser)*
c) *In huge font: dollars per year produced per year (round to nearest cent)*
d) *Cost per panel (default $430) round to nearest dollar (can be over-ridden by user)*
e) *Cost per panel after 30% tax credit round to nearest dollar*
f) *Years to payback round to nearest tenth of year*
g) *Dollars per watt (rounded to the nearest cent)*

This task was completed and tested. Design iterations with the client subsequent to the CRADA SOW changed the format of the initial screen shots in the CRADA document. Note that these capabilities are all evidenced by Figure 4 and Figure 5 below.

11. The main screen of the phone output is including graphic provide by 1SS. (at end of this document)

This task was completed and tested. Design iterations with the client subsequent to the CRADA SOW changed the format of the initial screen shots in the CRADA document.



Both the icon for the app on the phone (above) and the graphics within the app (as demonstrated in the Figures in the appendix) were reviewed and approved by the CRADA partner.

12. Utilize React Native (not Swift) as the source language. In this way, a substantial amount of the iPhone code will run on Android. One language on both devices. For the iPhone app, use native iOS elements if available.

The code used for development was/is React Native and NREL delivered the code to the client in this language. This is evidenced by the code base and communication with the CRADA partner.

13. The results of the annual production simulations will be displayed in the App and will be available for sharing through native iOS or android output apps. For example, text, messenger, mail, etc.

This was developed and tested. You can see the “mail” icon at the top of the About page in Figure 2.

14. All numbers will read out live. Meaning, they update continually as the phone is moved to change its azimuth and tilt Unless the user has locked the position. If the phone is tilted 5° past vertical the computed numbers should go blank, indicating to the user that this is not a valid position for the program. The idea here is to be able to read out numbers for wall mounted panels (tilt = 90°) but go blank if tilted past that. In phone position 90° to 95° the phone should display the data for 90°. Past 95°, the compute number should go blank.

As indicated above for several other tasks, this particular development requirement required significant coding effort but was and remains a key feature of this app allowing rapid updating with the movement of the phone in the air.

15. Initial testing will be performed on a limited number of devices approved by NREL and 1st Step Solar. Testing of the PVWatts API will also look at the volume of web traffic to the API for anticipated app deployment levels commensurate with current PVWatts website usage.

This was completed both by NREL (roughly 5-10 devices on both Apple and Android platforms and both phones and tablets) and the CRADA partner. Both situations were tested with iPhone versions being tested more robustly.

16. NREL shall incorporate feedback from 1SS.

This feedback was given and incorporated on multiple occasions through the end of the CRADA timeframe. This can be demonstrated with a variety of email documentation upon request. This is also demonstrated in the initial drawings from the CRADA partner (Figure 1) to the final implementation.

17. Further testing shall be performed by NREL

This was completed as documented above. This task also anticipated testing after the CRADA partner released the app to the AppStore.

18. Testing shall be reviewed by NREL for final deployment to the App store.

As indicated above, this testing was performed periodically through the end of the CRADA timeframe. Unfortunately, the final push to the app store was not completed by the CRADA partner by the end of the CRADA timeframe so final testing was not possible.

19. After initial iOS device development, Android development with the same functionality will be implemented.

This was completed and delivered to the CRADA partner via GitHub.

20. Graphics/Logos will make this clear that this is an NREL/DOE authored app.

This is true within the code base, and you will see that in Figure 2

21. Technical support will run continue for the duration of the 12-month funding window for this CRADA, after the iOS and Android apps have been delivered to the respective app stores. This

support includes updates for changes to iOS and Android operating systems. This support includes bug fixes. This support includes incompatibility with iOS or Android compatible devices that may not be discovered until the app comes into significant use. An anticipated needed level of funds for this support will be maintained by the development team for this support.

Technical support was provided through the CRADA timeframe. Unfortunately, due to the client not finalizing posting of the apps on the respective app stores, we are unable to respond to any feedback.

22. Subsequent to this CRADA's expiration, the SAM team will in good faith support (via DOE funds primarily, subject to available funding) the app while the solar system modeling tool capability is maintained at NREL (including PVWatts and SAM). NREL has no anticipation that this broader effort will not be maintained.

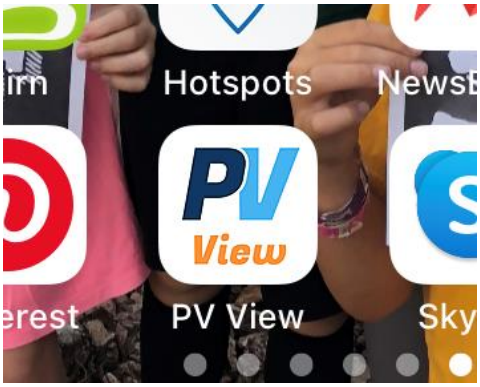
This task is ongoing but requires no effort at this time because the CRADA partner has not gotten the code/app into the publicly available locations. If that occurs, the SAM team would continue to work with them to integrate any updates from SAM/PVWatts into their app in the future.

23. The app must support all iPhone and iPad models sold within the last 2 years (minimum historical compatibility).

This was true when the code was delivered to the CRADA Partner.

24. The name of the app in both the iOS and Android stores will be provided by 1SS.

This was agreed on and deployed in the final set of code. The app name is visible in the icon on the iPhone as well in the beta version.

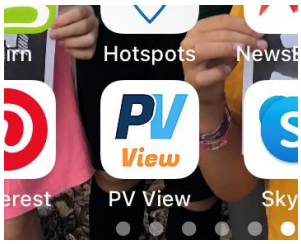


25. A swipe left gives a "who we are" page (also known as the About page). A swipe right gives a details page that has monthly comment similar to the web version of PVWatts. The main page contains information pop-up pages as indicated. The background of the app is a ghosted version of a 9x4 cell solar panel. This suggests that the phone is a scale model of the solar panel.

This development feature was included but the background of a "9x4 cell solar panel" was eventually replaced with the plain blue background shown in all the figures in the Appendix.

26. The icon as it appears after installed on a smart phone shall include graphic provided by 1SS.

Again, this figure is shown below as it displays in the iPhone.



27. NREL will participate in a joint press release stating availability of NREL-developed smart phone app.

This task was not completed because the CRADA partner has not yet made the apps publicly available for download and usage. NREL would be happy to complete this task using non-CRADA funds when this event hopefully happens in the near future.

Summary of NREL efforts:

NREL utilized the funds from the solar American Prize challenge voucher funds to create the code to call and translate the results of a PVWatts solar-production analysis. The development and testing of this app were completed on both Apple and Android phone operating systems. This code was handed off to 1stStepSolar (or Team Catalyst), the participant in this CRADA. The versions of the app were posted to a non-public area (potential users needed to provide their email addresses) of the Apple and Android shops and were downloaded to various mobile phones. The testing continued and several iterations and upgrades were made to the application via feedback from the client (1stStepSolar). That handoff occurred on July 3, 2020 at the private GitHub repo shared with 1stStepSolar. NREL staff and subcontractors have continued to provide support to the client as they intermittently worked through initial setup issues to launch the code and now are needing to make some additional minor library and other updates to handle updates for the Apple operating system. However, the screen capture images in the Appendix (from an iPhone). With this information, photos, video, and code, NREL has demonstrated completion of the tasks (with minor modifications in conjunction with the CRADA partner) above.

Current Status of Products:

The current status of the mobile product is that the client has received and now modified and updated the code. As of our last contact with them, they were dealing with one or two minor bugs and updates. One of the complexities of this development environment (which was the client's choice) is the fact that changes by Apple and Android in the operating system will require minor updates to various libraries and other code pieces (outside of what NREL and the client have written). Our collective anticipation is that the app will be available in the Apple and Android app stores very shortly.

Subject Inventions Listing:

None

ROI #:

None

Appendix: List of Figures

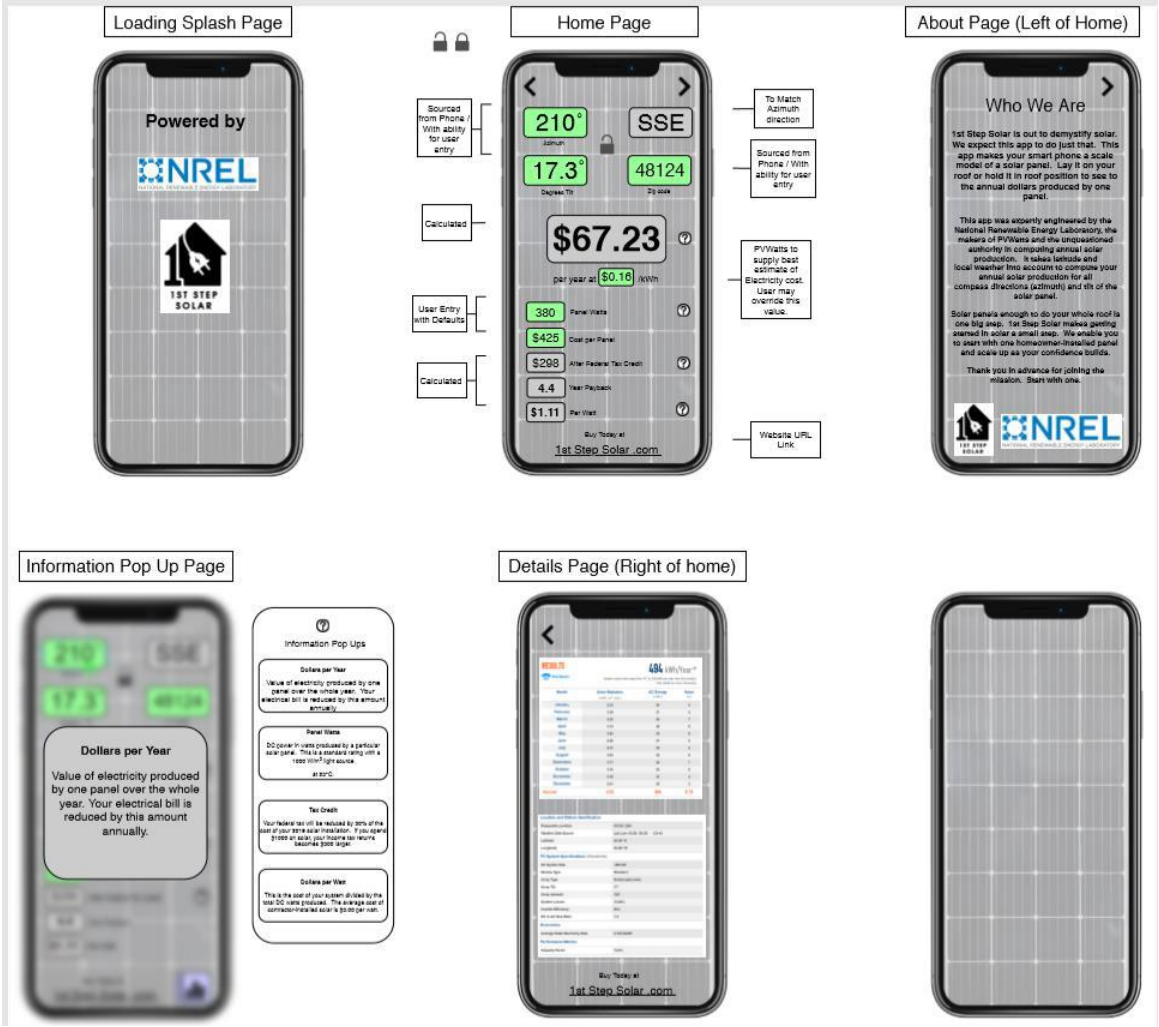


Figure 1. Initial Images for the PVWatts Mobile App as envisioned by 1st Step Solar

Figure 2. "About" Page which describes 1St Step Solar – developed by NREL

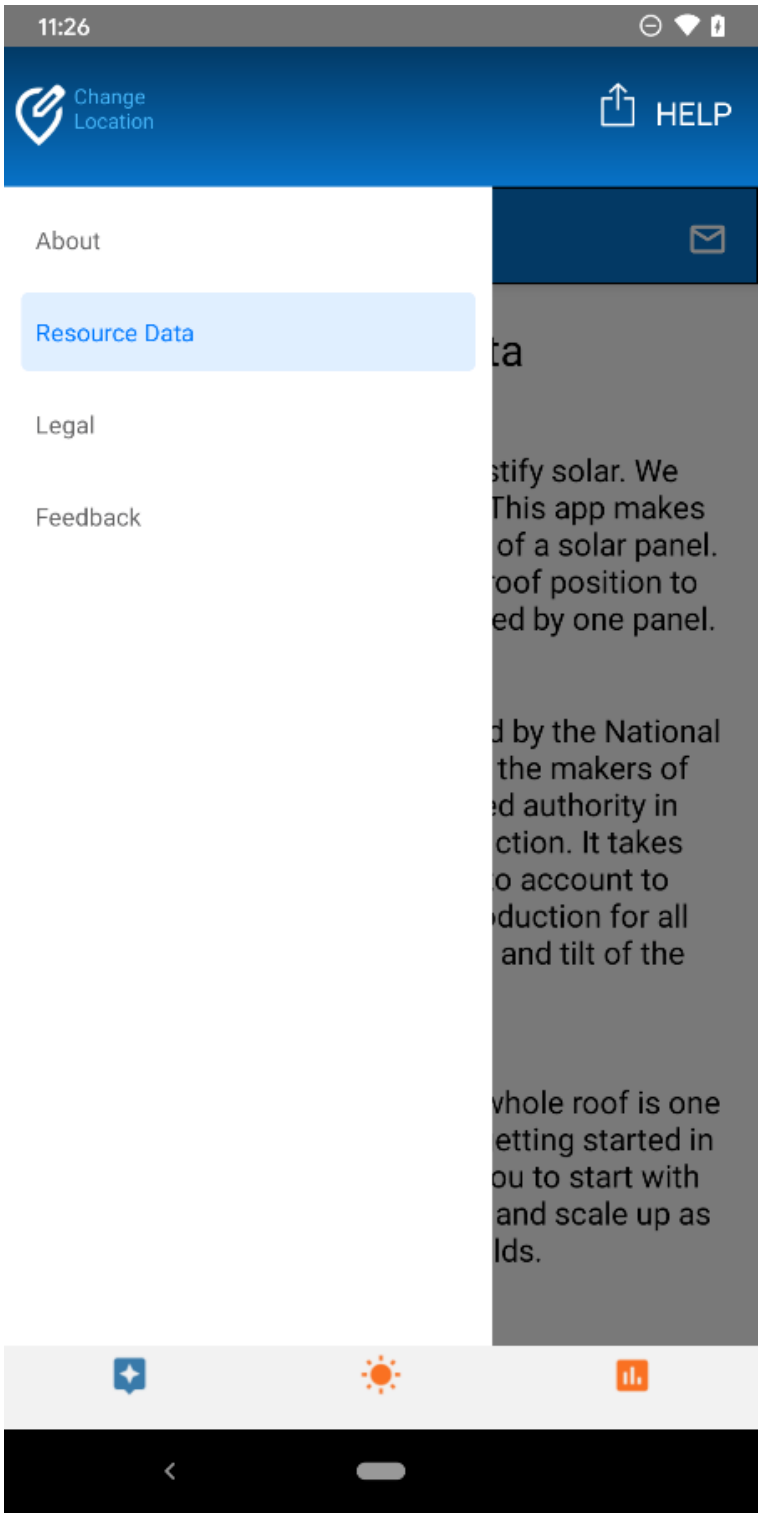


Figure 3. The Drop Down Menu for the App as developed by NREL

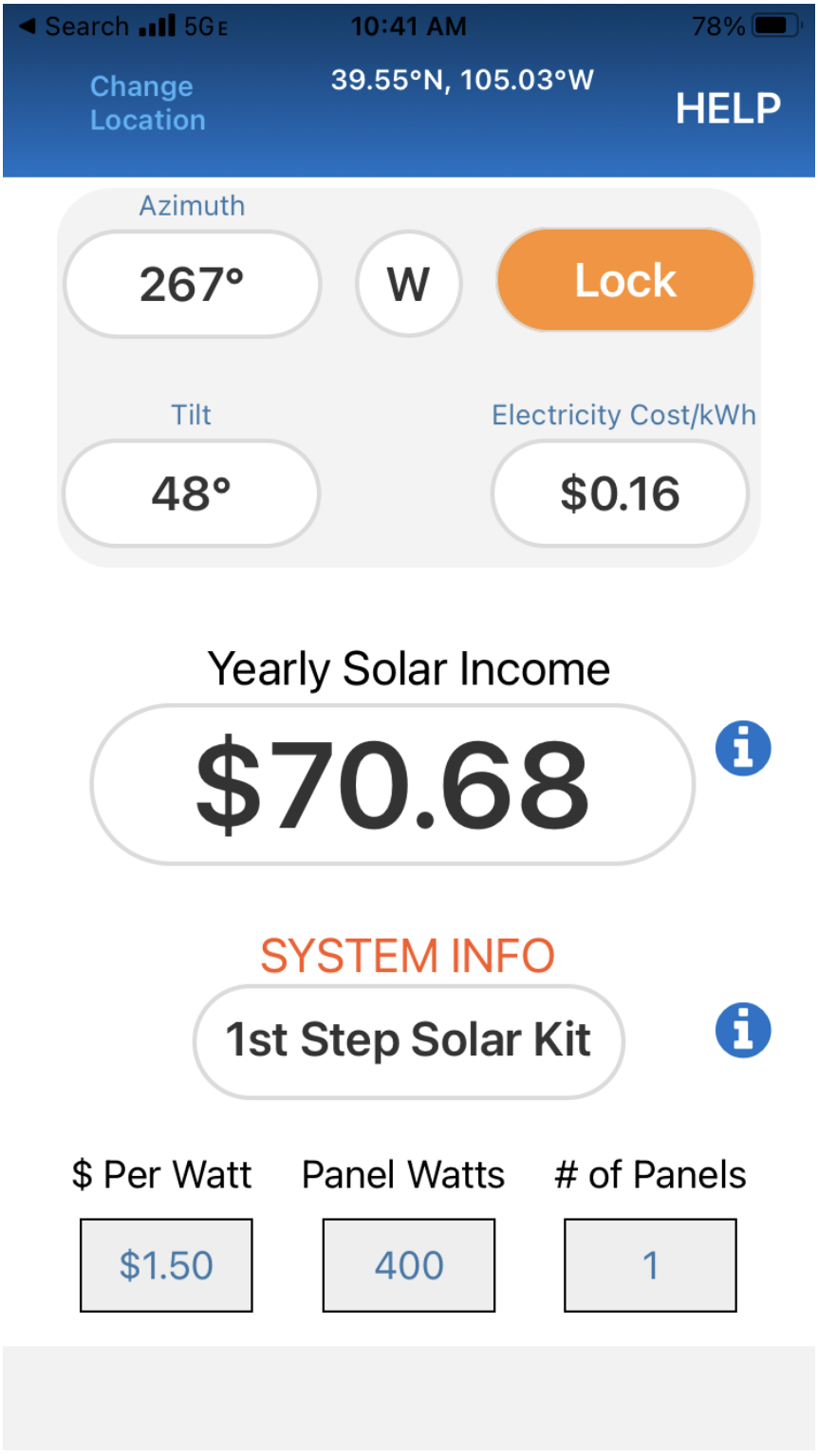


Figure 4. Active Results Page ("Yearly Solar Income" Changes as phone is moved)

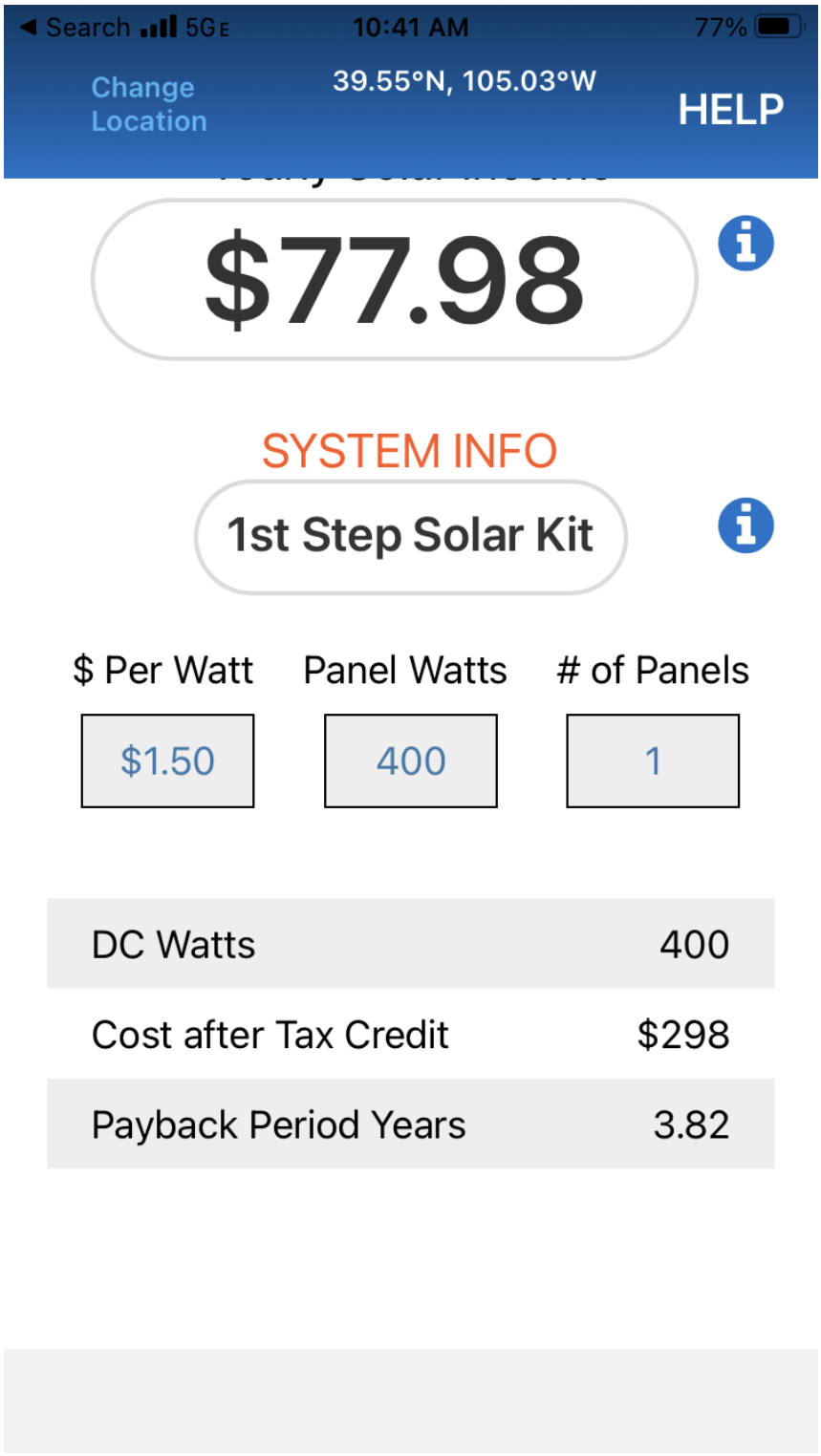


Figure 5. Bottom Portion of Active Page with additional outputs

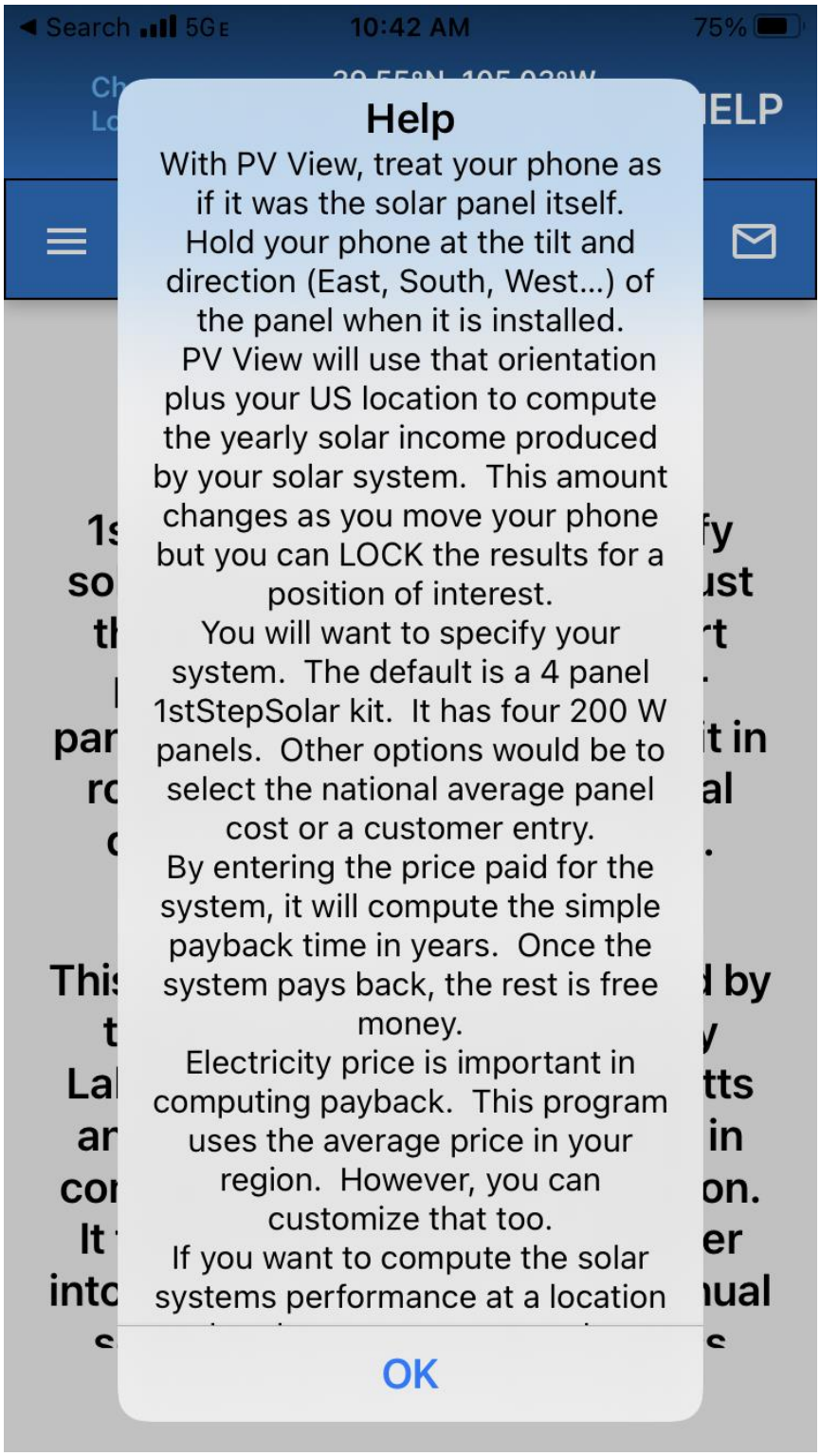
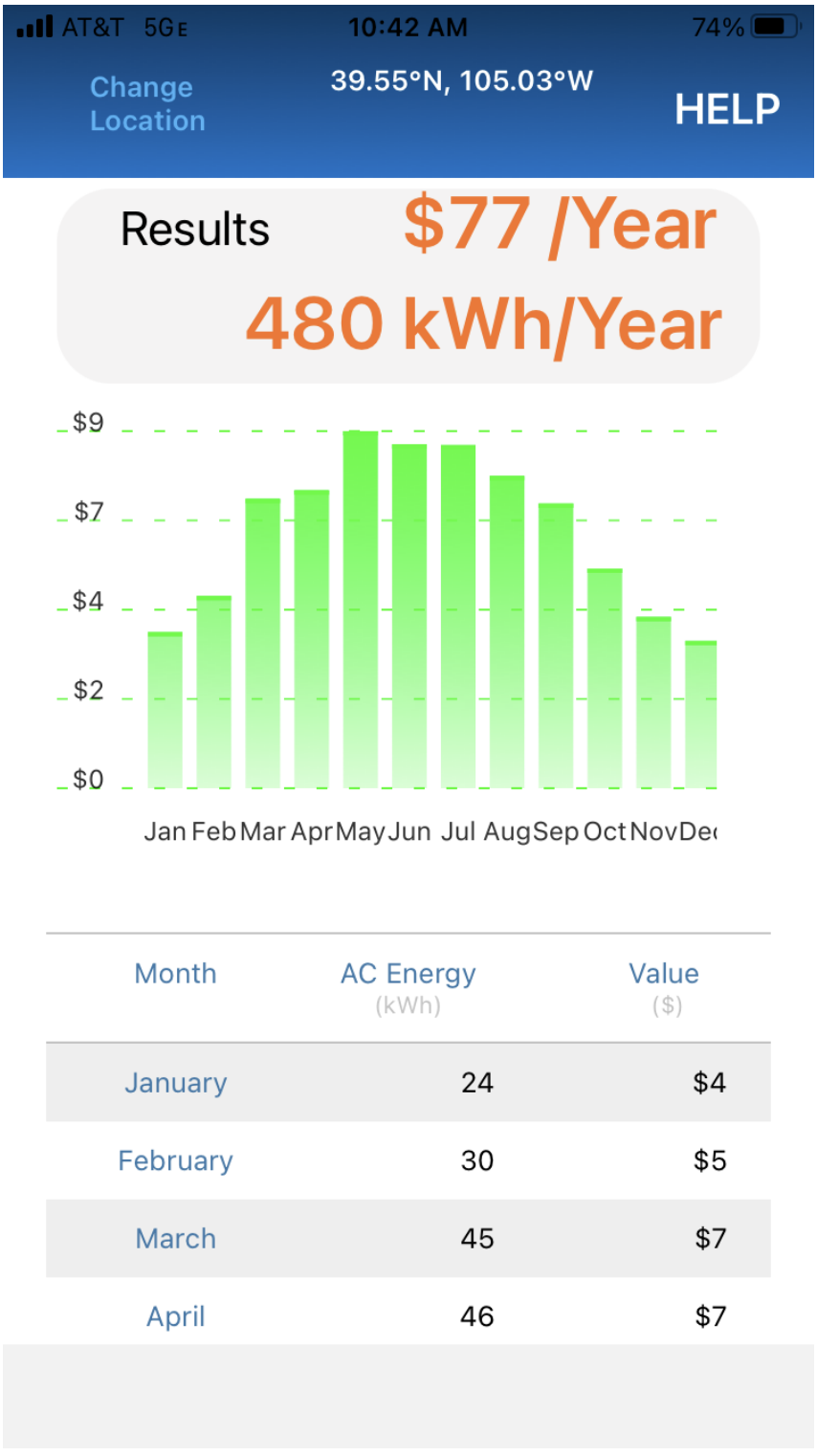


Figure 6. The "Help" menu in the app as developed by NREL



Month	AC Energy (kWh)	Value ($)
January	24	$4
February	30	$5
March	45	$7
April	46	$7

Figure 7. The Monthly Results that Mimic the online PVWatts results

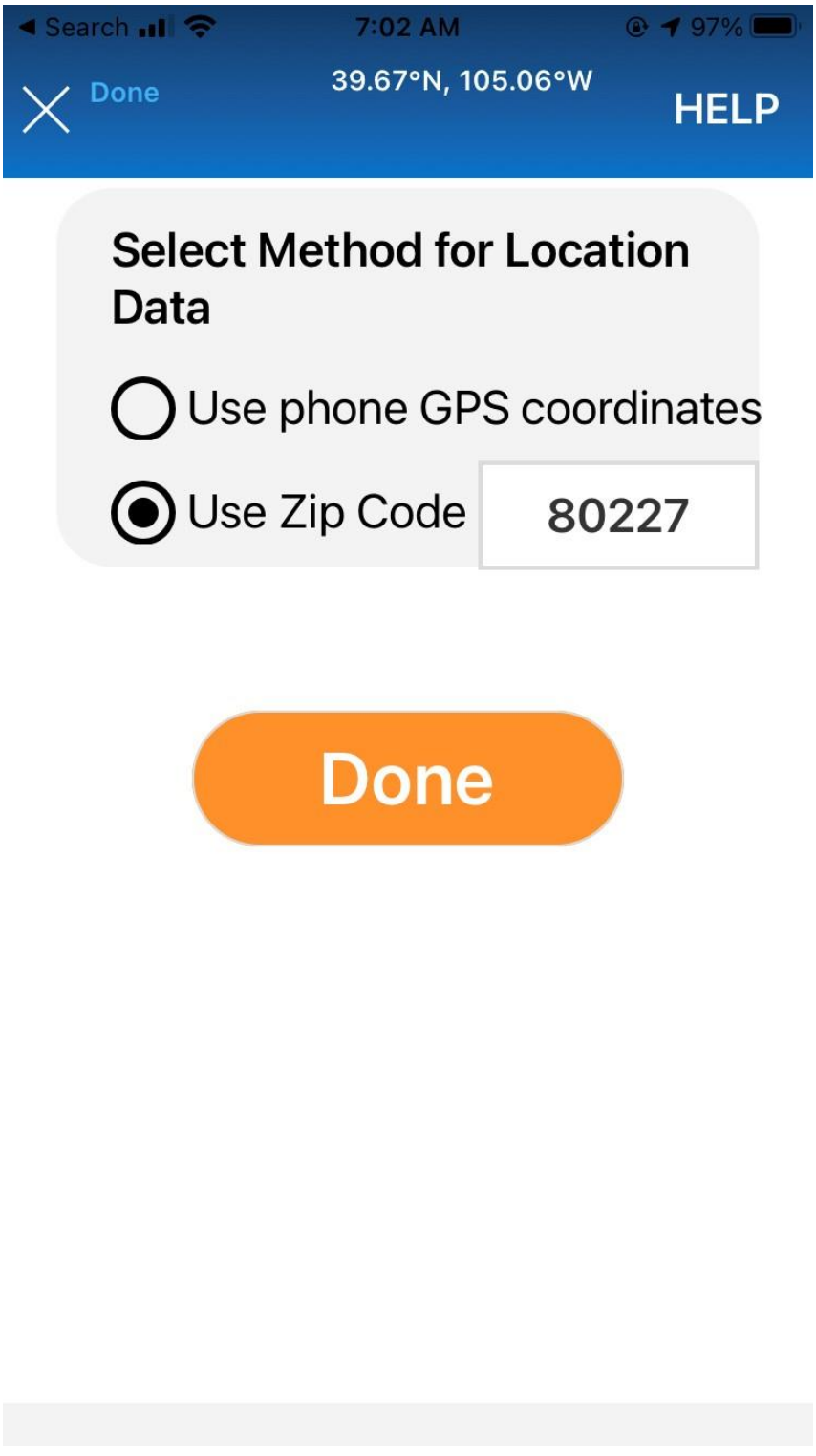


Figure 8. Ability to Change from Current Location to Alternate Location