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Sustainable Energy Technology Mobile App for Site Surveying and Best Practice Reference

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DECLARATION OF ORIGINALITY

Title of Dissertation

Sustainable Energy Technology Mobile App for Site Surveying and Best Practice Reference

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Name **Matthew Klimuszka**

Signed ....

Dated ....

ABSTRACT

Smartphones are becoming increasingly common and their environment sensors are more accurate and varied than ever. As sustainable energy installations increase, the power of mobile devices can be harnessed to distribute best practice guides and streamline the process of surveying installation sites. Such an application (app) can be used by the layman for education and an estimate of their property's potential for energy solutions. The professional can use the app in concert with additional software packages to hasten work and to provide quick reference to regulations. A publication quality Android app called Helios was created that contains a photovoltaics best practice guide adapted from *Guide to the Installation of Photovoltaic Systems* distributed by the Microgeneration Certification Scheme and a solar thermal guide adapted from *Solar water heating systems – guidance for professionals, conventional indirect models* created by the Solar Trade Association. It also contains utilities to measure roof parameters, estimate photovoltaic production, and take notes in both textual and graphic forms. This data can be exported to be implemented in a larger context.

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§ 1 Introduction

On-site guides are important sources of information for engineers and installers doing field work. For example, the IET provides regular updates to their official guide, the most recent being *On-Site Guide BS 7671:2008 (2015)*. This provides best practices and easy to reference regulations for general electrical work. Sustainable energy technologies provide their own unique challenges, such as photovoltaics being always electrically live. It is important that best practice documentation is available for sustainable energy technologies to ensure safe installation and maintenance.

Distribution of these materials has been less than optimal. Many professionals in the field do not realize that guides for sustainable energy technologies exist. Voids exist in this industry that can be filled by standardized documentation and software. Another expanding technology, mobile applications, may be the way to distribute best practice materials. This can also be the start of a new way to perform site surveys for potential sustainable technology installations: using the always connected computers that most people carry with them every day.

§ 1.1 Project Plan

§ 1.1.1 Original Project Plan

Best practice guides for various technologies were to be written with guidance and in partnership with Sasie Ltd. Compliance with Microgeneration Certification Scheme (MCS) and IET standards is required. It was expected that at least three guides would be written and formatted to publication quality.

This plan quickly fell apart, as best practice guides for photovoltaics, solar thermal, heat pumps, and small wind turbines have already been published by respected organizations (Table 1). Although some of the guides could benefit from updates, that alone would not be appropriate for a dissertation. The guide of highest priority, photovoltaics, is only a few years old, but the solar thermal guide is the next highest priority and is almost 10 year old.

Name	Organization	Updated
Guide to the Installation of Photovoltaic Systems [1]	MCS, ECA	2013
Solar water heating systems – guidance for professionals, conventional indirect models [2]	Solar Trade Association	2006
Installing small wind-powered electricity generating systems [3]	Energy Saving Trust	2004*
Environmental good practice guide for ground source heating and cooling [4]	Environment Agency	2010*

Table 1: *Existing best practice guides. An * indicates that no publication year is listed in the document, so the most recent year referenced within the document is listed instead*

§ 1.1.2 Existing Mobile Apps

The original project sought to condense various regulations, installation guides, and research into an easy to carry and easy to reference format. Since much of the data has already been compiled, reducing documents into mobile applications (apps) could be a logical extension of the project. But first, the existing apps must be surveyed.

Since the author owns and is most familiar with Android devices, this is the platform that was inspected. Searches were done on Google Play™ for apps that provided installation documentation or site surveying capabilities for photovoltaic, solar thermal, small wind, and heat pump systems. The applications were filtered by English language and minimum 4 star ratings. Using these filters, only photovoltaic apps were found, although irradiation and shading calculations could be used for solar thermal as well. The 4 star rating was relaxed for the other technologies, but that only added one wind app to the list. The results of this search are in Tables 2 and 3.

Each app was downloaded to a smart phone and tested. The Google Play store's return policy was used to test paid apps. The app's features were recorded along with the number of downloads, date of last update, price, and the author's notes for special cases. Out of the 18 apps tested, only 4 have any references to regulatory bodies. Only one app, EpiShade, has a reference to the MCS.

This market analysis shows that there is an opportunity to launch sustainable energy installation reference documentation as an app on the Android platform. There is also a lack of surveying utilities that follow MCS guidelines. Reliability of results is also questionable. Of the applications that do produce useful figures such as irradiation values and shading coefficients, only Solar Shading explicitly states the calculations it uses (although EPiShade appears to use standard MCS shading methodology). They all rely on the accuracy of the device's sensors, and only SolarMeter solar panel planner provides a calibration menu. For the rest of the apps, there is no indication of how accurate the readings are.

Google Play is a trademark of Google Inc.

App	PV Orientator	PvGPS	PV Calc	PV Toolbox	SolarMeter solar panel planner	Solar Shading	Irradia Solar PV	SolBuddy	EPiSunTools
Updated	5/15/14	7/27/12	2/22/14	1/7/14	5/31/14	10/29/14	3/26/15	8/20/13	10/2/14
Installs	10 – 50	50 - 100	10 – 50	1,000 - 5,000	1,000 - 5,000	1,000 - 5,000	1,000 - 5,000	100 - 500	500 - 1,000
Price	$1.00	$1.00	$2.00	$2.00	$5.00	$16.00	Free	Free	Free
Notes		Couldn't get GPS to work	Must enter info, calculates losses and current	Calculates sun rise / sunset times		Would not calculate coefficient.	Poor UI, not clear results, gets data online	Satel-light database, Europe and North Africa.	Shows sun paths, easy angle measurement
Regulatory Body						NOAA			
Explained Calculations						X			
Safety Tools									
Shading Measurement						Two auto methods			Surveying objects
Usage Calculations									
Manual Location option					X	X		X	
Irradiation		X			X	X	X	X	
Optimal PV position	X								
Other Electric Details			X	X					
Panel Library				X					
Compass				X		X			
Calibration					X				
Wind									

Table 2: *Relevant English language apps on the Play Store rated at least 4 stars as of 9 July 2015, unless noted otherwise. [5]-[13]*

App	SimplySolar	Solar Calculator	TagPrint Xpress Solar	Solar Site Design	PV OptiMizer	EPiShade	Work safely with PV systems.	Volta Solar Calculator	Wind Turbine Estimator beta
Updated	9/3/12	6/27/15	4/2/15	5/5/15	5/28/15	7/8/14	11/5/14	10/11/14	11/11/13
Installs	1,000 - 5,000	5,000 - 10,000	100 - 500	1,000 - 5,000	100 - 500	100 - 500	100 - 500	100 - 500	10,000 - 50,000
Price	Free	Free	Free	Free	Free	Free	Free	Free	Free
Notes		Glorified spreadsheet	Main functionality is printing	Surveying form. Sends data for analysis	Designed for Australia, confusing UI	Has manual object addition and camera mode, but crashes on HTC One Mini	Hangs on loading screen.	Nothing more than an empty spreadsheet	3.9 Star rating. Put in turbine specs.
Regulatory Body			NEC			MCS	GSA		
Explained Calculations									
Safety Tools			Prints labels, descriptions				Unclear, won't load		
Shading Measurement						Camera and manual			
Usage Calculations		X						X	
Manual Location option	X								
Irradiation									
Optimal PV position	X								
Other Electric Details		X							
Panel Library									
Compass									
Calibration									
Wind									X

Table 3: *Relevant English language apps on the Play Store rated at least 4 stars as of 9 July 2015, unless noted otherwise. [14]-[22]*

§ 1.1.3 *New Direction*

This project now aims to fill the void on the Google Play store by developing a marketplace ready app. It will help determine a location's renewable potential and provide installation reference material that is easy to navigate, concise, and adherent to MCS requirements. Goals/deliverables are listed below in priority order.

Minimum goals:

1. Produce a working Android app that meets current style expectations
2. Photovoltaic best practice guide optimized for smart phone and tablet navigation
3. Solar thermal best practice guide optimized for smart phone and tablet navigation
4. Clarity in all references and methodologies used within the app
5. All reference materials available offline

Additional goals:

1. Add additional updated information to the best practice guides
2. Production estimation utility
3. Shading coefficient measurement utility
4. Solar thermal sizing utility
5. Heat pump best practice guide optimized for smart phone and tablet navigation
6. Calibration and verification for all sensors
7. Submit app to Google Play store
8. Small wind best practice guide optimized for smart phone and tablet navigation
9. Wind potential application

The original timeline submitted in May has become obsolete due to this change in direction. Since the rate of progress was uncertain, no detailed plan was created except for the goals listed above, and even they changed throughout the process. Instead of a plan, actual progress was logged and it is represented in Appendix A. Throughout the project, there were regular supervisor meetings which were recorded on specialized sheets. Copies of these sheets are in Appendix B.

§ 1.2 <u>Android</u>

§ 1.2.1 *Market Share*

Android version 1.0 G1 launched in February 2008 with fewer than 40 apps in its marketplace, since then, it has grown tremendously [23]. The latest version, 5.0 Lollipop, was launched in October 2014, and along with it a new style guide called *Material Design* [23]. Worldwide, hundreds of millions of mobile devices run Android, with over a million new activations every day [24]. It's ability to run on a large variety of devices has given it a large advantage over iOS in recent years. In the first quarter of 2015, Android powered devices made up 78% of smartphone shipments, with Samsung as the leading manufacturer (Figure 1) [25].

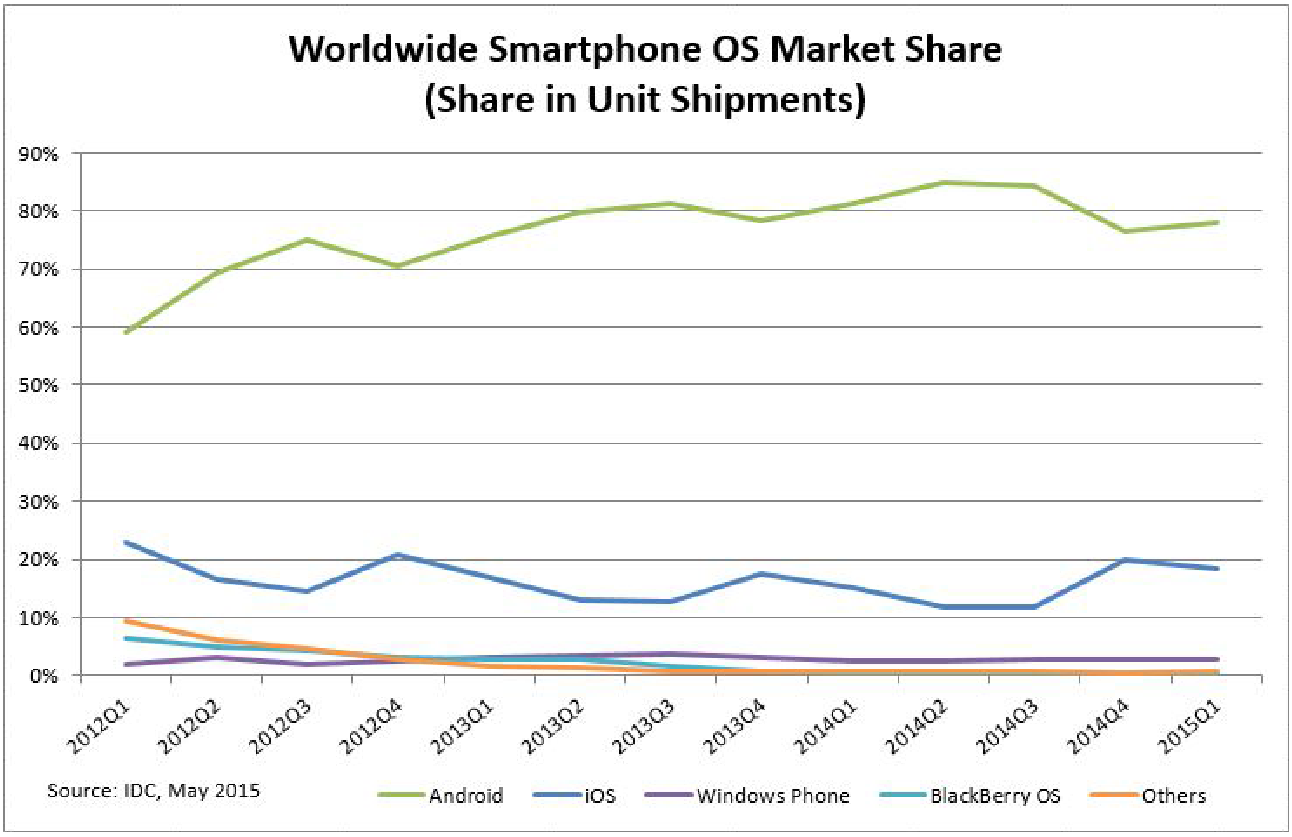


Figure 1: *Market share data over the past 3 years shows that Android sits firmly above its competitors [25].*

The target audience of this app resides in the geographic area that must abide by MCS regulations. It is important to ensure that the Android platform is popular enough in the UK to warrant this app's creation. The UK Android share is smaller than the worldwide share at 52.5% vs 78%, but it is still the largest OS on the market (Figure 2).

Within Android, there have been eight major releases, and 22 versions of the API. Each one supports different features, but they are backward compatible with apps designed for older versions. When developing an app, a minimum version and target version are chosen. This determines what features are available and what devices can download the app using the Google Play store. In order to decide what these versions should be, the current distribution must be taken into consideration, which is shown in Figure 3. It is expected for a new app to support around 90% of active devices [28]. With that in mind, setting a minimum version of Jelly Bean or Ice Cream Sandwich would be appropriate.

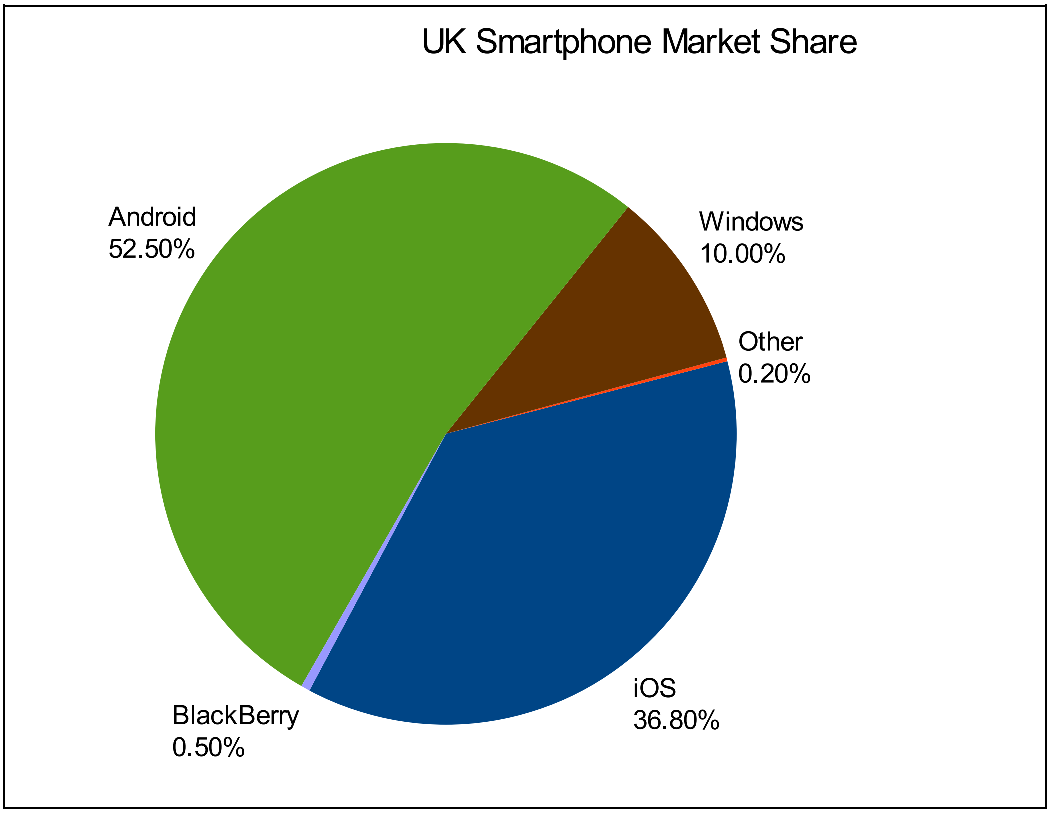


Figure 2: *Android has a smaller share in the UK, but it is still the largest OS on the market [26]. This data is from March, April, May 2015.*

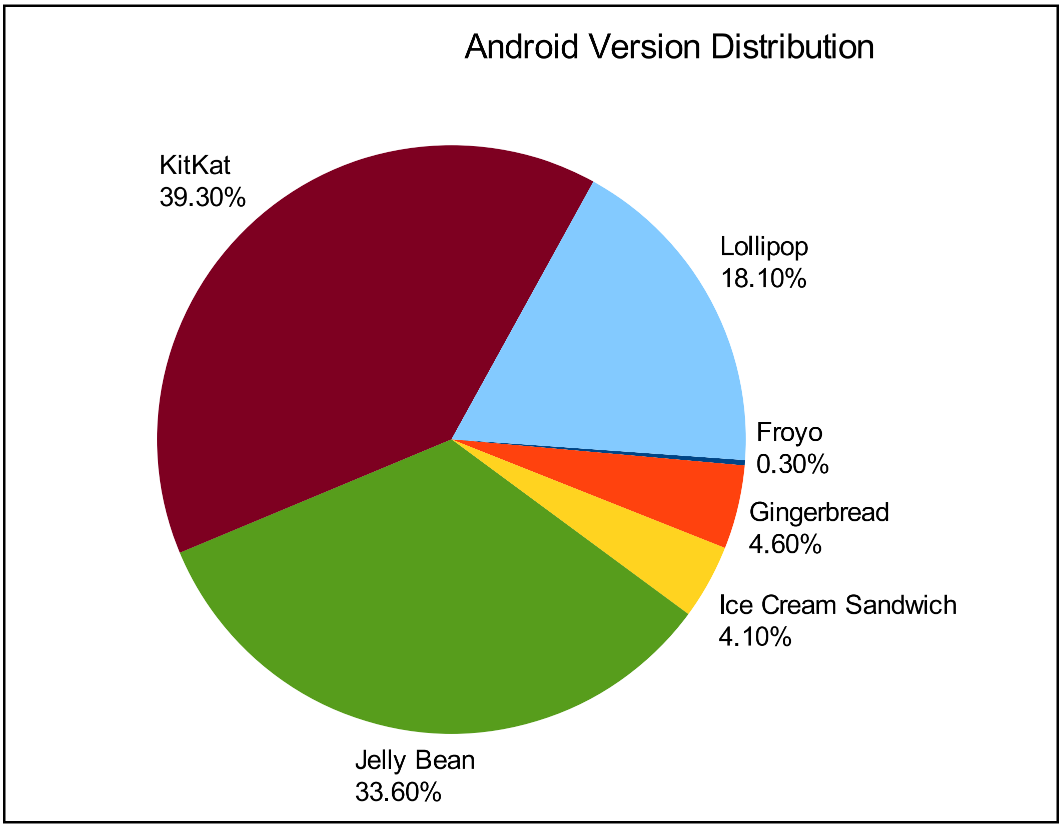


Figure 3: *Distribution of Android versions that accessed the Play Store during the seven day period ending on August 3, 2015 [27] . Newer versions are later in alphabetical order, i.e. Lollipop is the newest.*

§ 1.2.2 Development Environment

The official software suite for android developers is Android Studio [29]. Eclipse was the favoured option before Android Studio's recent 1.0 release in December 2014 [30]. MIT's Android App Inventor was also considered because it requires little to no experience in Java. Upon inspection, this tool does not support the latest Android features. Therefore it was passed over in favour of Android Studio.

The studio contains a code editor with advanced analysis features; templates for a variety of app types; github integration for version management; support for multi-screen apps; and an emulator that supports phones, tablets, wear, and televisions. It can be run on Windows, Mac OS X, and Linux. The author is using a Windows installation. [31]

In addition to the emulator available in Android Studio, there is access to two physical devices for testing. The first is an HTC One Mini, a smart phone with a 4.3” screen [32]. The other device is a HiSense Sero 7 Pro, a tablet with a 7” screen [33]. Additional information about this hardware is in Appendix C.

§ 1.3 Design

§ 1.3.1 Priorities in App Design

> “'The opposite of love is not hate; it’s indifference.' In a world where there are already hundreds of thousands of mobile apps to choose from, indifference is failure. “

Text Box 1: *Mike Gualtieri of Forrester Research Inc. uses Nobel Peace Prize winner Elie Weisel's words on love to describe what makes an app successful. [34]*

In order for an app to be successful, it must be more than just bug free. It must stand out and its use must be enjoyed, not just tolerated. In *Mobile App Design Best Practices*, Gualtieri claims that a loveable app includes a compelling user experience, which he defines through usefulness, usability, and desirability. Usefulness revolves around functionality; usability is marked by ease of use; and desirability requires inspiring positive emotions. [34]

Usefulness is the the most straight forward part of design. A user first encounters an app's features on the associated Google Play store page, setting an expectation of its capabilities. It is important that these features are available immediately after installation. This requires that the features work and that they are easy to access (usability). Google Play store review statistics indicate that 44% of users will uninstall an app immediately if it does not perform as they expect [35].

Even if an app has every feature that a user needs, it means nothing if they cannot be utilized quickly and easily. The user should be able to quickly learn how to use the app, and it should respond quickly to requests. In *Display and Interface Design: Subtle Science, Exact Art*, Bennet describes two main methods of learning how to use a piece of software: detailed instructions and learning by doing. Instructions are useful in complex and safety critical domains. For most items, however, the modern user greatly prefers learning by doing [36].

Desirability is the most abstract metric. It means users enjoy the app. This can come from a variety of things, such as pleasing aesthetic. Recently, developers have begun “gamifying” apps by adding points and achievements that can be shared with friends. This encourages people to try new things within the app or spend more time repeating actions [37]. A 2013 study showed that the playfulness of an app (defined by the pleasure of engagement) is of major importance to a consumer's favourably towards it, equal with return on investment [38]. It is not just enough that an app is easy to use and fulfils expectations, but it also must engender positive emotions in order to be successful.

In *Interaction Design*, a slightly different list is presented: effectiveness, efficiency, safety, utility, learnability, and memorability (easy to remember how to use). This mostly overlaps with what has been discussed. Gualtieri and Bennett both talk about the importance of reversible actions, but *Interaction Design* expands on this with its safety requirement. A safe interface reduces mistakes and misclicks by using warning dialogues and keeping dangerous menu items (close, delete, etc.) far away from commonly used actions (share, save, etc.) [39].

§ 1.3.2 Native vs. Web

There are two ways that a mobile app can access data and perform operations, natively or via the web. For each project, a decision must be made on what blend of these two strategies should be used. PC Magazine Glossary gives the following definitions. A web app is "An application in which all or some parts of the software are downloaded from the Web each time it is run. [40]" A true native app is "An executable program coded in the machine language of the hardware platform it is running in. [41]" Using this definition, no Android app is truly native, because they are compiled by the Android Runtime (and previously Dalvik) when they are launched instead of when they are installed or distributed [42]. In the context of an Android system, however, an app that does not require the internet to function can be called native for performance considerations. Many apps are also hybrids of these systems, running natively but pulling data from the web.

Web apps can have compatibility across multiple operating systems, since they can run in a browser. They can also harness the specific abilities of a developer if they know HTML, CSS, and Javascript, but not the languages required for native development. Native apps, on the other hand, can run faster, since nothing has to be transferred through a data connection. Native apps are also commonly considered more user friendly because they integrate better into the OS [43].

This project will use no web resources, since it is intended to be used primarily on-site. During energy technology installation and surveying, mobile data access may be limited. For maximum reliability, all reference material and data will be stored within the app. Diagrams and images will be made in vector format if possible to minimize the required storage space.

§ 1.3.3 Obstacles to a Bug Free App

Even if an app has killer features, an intuitive UI, and makes every user smile, people still need to download it and it has to work bug free. A study on iOS reviews found that the most common complaint reports a functional error (27%) followed by feature request (15%), app crashing (11%), and network errors (7%). The other 40% of negative reviews were concerned with content or were largely not specific [44]. These reviews are important. A qualitative study of 30 users found that ratings were a key determinant in purchase [45], and data mining from 30,000 BlackBerry apps found a strong correlation between an app's rating and its number of downloads [46].

Android's ability to run on a wide variety of hardware configurations is possibly its greatest strength, but numerous authors point it out as the greatest challenge when developing an app. Kathuria and Gupta list major issues: different screen sizes & resolutions, different Android versions, limited capabilities of different devices, weakness of testing on emulators, and lack of software/hardware integration [47]. Testing across many device parameters is recognized as being the solution to this, but there is a distinct lack of automated solutions [34], [48].

Some differences to test against are obvious, like screen resolution, but some problems can be much more surprising. A team from Dartmouth College doing app store research with their own software found that very small differences between devices could ruin an app's functionality [49]. For example, the frequency response differences in the iPhone 2G and 3G microphones required different parameters to detect specific sounds. Another variable that they were surprised by was that jail-broken phones introduced unexpected behaviours in their application. A study from Microsoft Research highlights that many parameters are difficult to replicate in the lab, such as network signal, GPS strength, and battery level, all of which influence the environment in subtle but important ways [50].

§ 1.3.4 Interface Design Strategies

> "There will be no foolish wand-waving or silly incantations in this class. As such, I don't expect many of you to appreciate the subtle science and exact art that is potion-making. However, for those select few who possess the pre-disposition [...]"

Text Box 2: *Bennett compares the "subtle science and exact art" of interface design to potion making in Harry Potter and the Sorcerer's Stone [51].*

Since the introduction of the GUI, users have been able to interact with software using images and icons, which furthermore allows users to explore and experiment with an application. Both Bennett and *Interaction Design* highlight two important features of an interface that facilitates learning: (1) the ability to reverse an action and (2) using recognizable metaphors (motions, icons, etc.) to interact with an object [36],[39]. As evidenced by Android's decision to have home and back as the only buttons required on the front of all devices, the ability to go back is central to one's experience on the platform. This allows a user to explore an app while knowing they can always reverse their decisions and return to familiar territory.

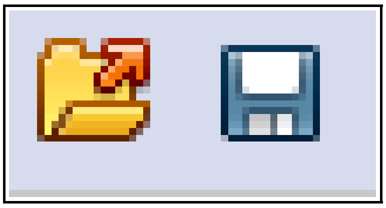


Figure 4: *Two icons in the OpenOffice interface serve as metaphors for opening and saving a file.*

The second feature, the metaphor, is more abstract. It allows users to understand what an action will accomplish without anyone explaining it it them due to the similarity to physical or digital objects that they already have experience with. An example of this is shown in Figure 4, which contains a screen shot from OpenOffice Writer 3.3.0. Even without having used the program before, it is immediately apparent that these icons allow the user to open and save a file. Although hanging file folders have never existed within a computer, a user can relate the physical process of accessing a file to the digital one. The floppy disk icon is unique in this regard, as it once referenced a physical object and now has meaning of its own. In this case, software designers rely on a user's familiarity with a common icon that means the same thing in many programs. In Android, the share icon (Figure 5) remains the same across all apps that have sharing capability, so the user can recognize the option from past experiences.

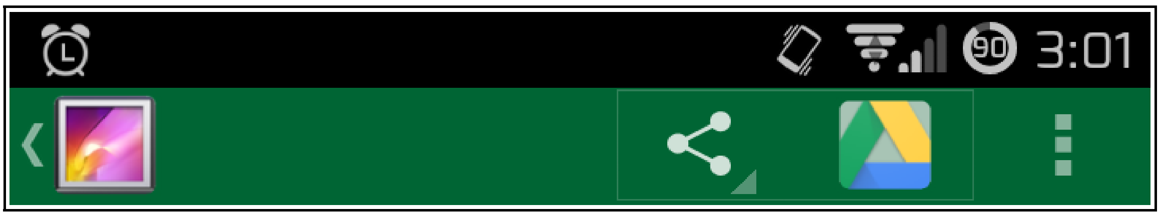


Figure 5: *In this screen shot of the action bar within the Android Gallery app, both types of metaphors are used. The Gallery icon is a framed photo and the share icon (three connected dots) represents the share action that is identical across many apps. The icons in the notification bar can be considered using the same metrics.*

§ 1.3.5 Current Interface Trends

Touch screens have revolutionized how we interact with technology. Users are no longer limited to a finite number of buttons, and digital interactions have come much closer to resembling physical interactions. Now users can tap, rotate, shuffle, and draw on digital objects just like they can with pen and paper. Thinking back to the metaphors described by Bennett, this allows every interaction within an app to draw on the meanings of physical objects.

In 2012, Google started experimenting with a pen and paper inspired interface when it introduced Google Now, which presents useful information on digital index cards [52]. In recent years, this paper and ink design has become popular. For example, Facebook uses cards to present individual posts. App icons have also simplified, often resembling a single colour sketch instead of a flashy computer graphic. These simple designs also have the advantage of being recognizable even when they are small [39]. In late 2014, Google introduced *Material Design* alongside Android 5.0. This style guide recommends that all apps use a pen and paper design that includes shadows and movement animations to give UI elements additional physical weight [23]. Google continues to update this style guide with the most recent update being September 1st [53].

To see how these design principles are implemented, marketing material for the top 10 free apps on the Google Play store are shown in Figure 6. The top free apps in a variety of categories are shown in Figure 7. Note the simplified one colour icons used in most of the designs. Elements are flat, but often with shadows or altered lighting to appear as cards floating just above the screen. The one app in this list that goes against that trend is Super-Bright LED Flashlight, but that is because it resembles the object it is trying to emulate. It has two controls that anyone who has used a flashlight before would recognize: a large power button and a spinning crown. A third button to toggle clicking sounds uses the standard speaker icon. This relation to physical objects is also prominent in the Netflix app, which lets the user sift through images like they would DVD cases.

These simple designs are not just easy to learn, they are also easy to see. The accessibility of an app is important to consider. Using a plain background with single colour text makes graphics easy to scale for magnification modes, and it reduces the need for high contrast options. With approximately 8% of men and 0.5% of women having some form of colour blindness, minimizing overlapping colours ensures that these users can use the app with minimal difficulty [54].

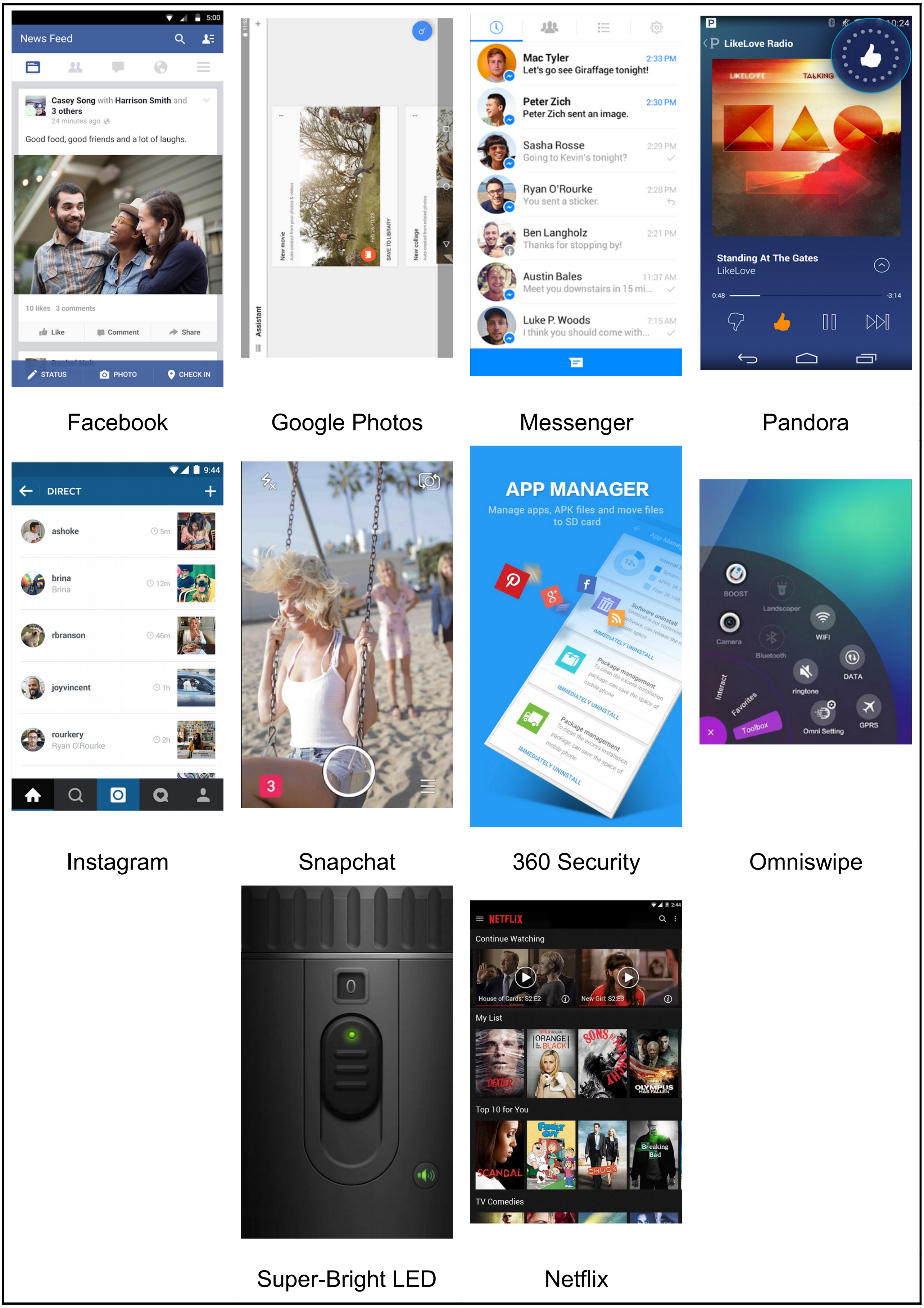
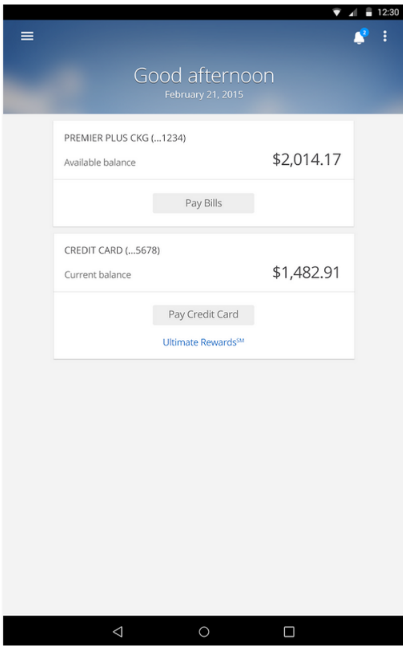
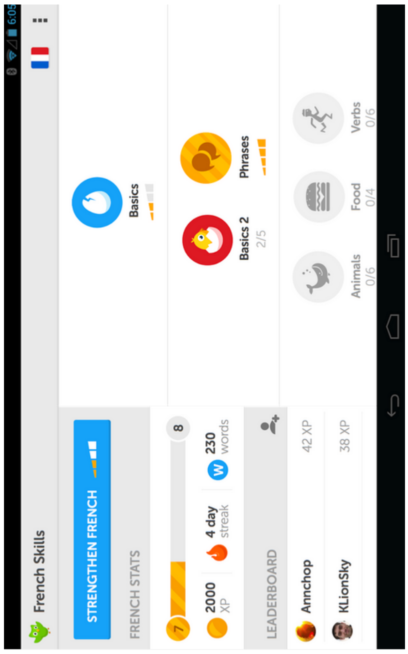


Figure 6: *Marketing material for the top 10 free apps on the Play Store as of 9 July 2015. [57]-[67]*





Super-Bright LED Flashlight

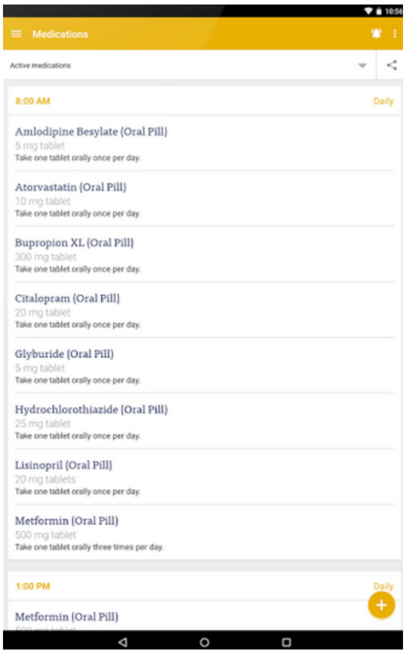
Productivity

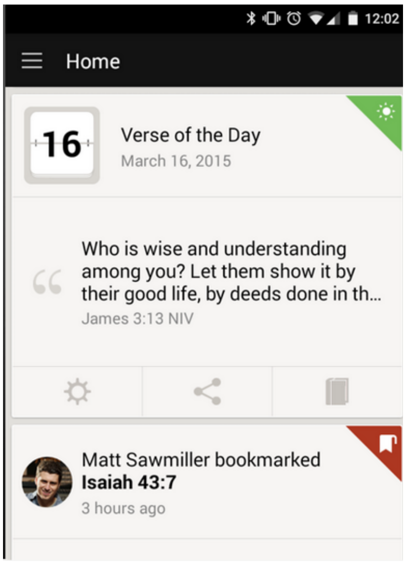
Chase Mobile

Finance

Duolingo

Education





Carezone

Medical

Holy Bible

Books and Reference

Figure 7: *Top free apps in various categories on the Play Store as of 9 July 2015. [66], [68]-[71]*

§ 1.3.6 Logo Design

Inspiration for the iconography was taken from the leading technology companies at the present. In July Facebook unveiled their new logo, and in August Google created a new parent company named Alphabet (Figure 8) [55],[56]. They both use simple sans-serif fonts with limited use of colour. They can be clearly read on any size screen and take up very little bandwidth when rendered on mobile devices.

Figure 8: *Company logos released summer 2015 for two of the largest internet technology companies [55],[56].*

§ 1.4 Learning Resources

Having no experience in Java, mobile development, SQL, or XML, a variety of reference materials was required. A base of vocabulary and general strategies for app development came from Udacity's online class “Developing Android Apps.” The class is designed and taught by Google employees, and it required a knowledge of Java [72]. Material from the first 3.5 lessons (out of 6) were watched, at which point the lack of Java experience became problematic.

From there, android developer documentation along with *Introduction to Android Essentials* textbook gave enough information to start coding [73],[74]. Android Studio provides template classes and XML layouts, which provided a solid base of code to start with. General debugging strategy was to search the internet for a description of the problem or the error message using Google [75]. This often lead to StackOverflow, a StackExchange website dedicated to answering programming questions [76]. This website had posted questions with answers for most errors that arose.

§ 2 Application

§ 2.1 Logo and Name

***Figure 9:** The logo uses an ellipse and colouring to evoke an association with Earth. This is the final version after two other iterations.*

“Helios” was chosen to be the name of the app. It means sun in Greek and is easy to remember. To mirror the simple and professional aesthetic of the app itself, three web-safe colours are used: a dark blue, a green, and white (Figure 9). These colours are reminiscent of the earth as seen from space, appropriate for for a sustainable energy app. The ellipse around the “H” strengthens this association. To match the style of the app's UI, an angular font is used, Consolas. Kerning is reduced to create a more unified look and the pip on the “i” is replaced with a green octagon to create a unique logo and provide a way to balance the colour. Overall, the icon conforms to the flat and bold style of modern app graphics.

The logo was made as a vector file in Inkscape so it can be reproduced as a high quality bitmap in any required resolution. The launcher icon is the “H” and the ellipse on a white square with rounded corners. This design looks at home next to the icons of industry giants, shown in Figure 10. Launcher icons for screens of various pixel densities were generated from the original SVG file using Android Asset Studio [77]. This ensures a consistent appearance across all devices.

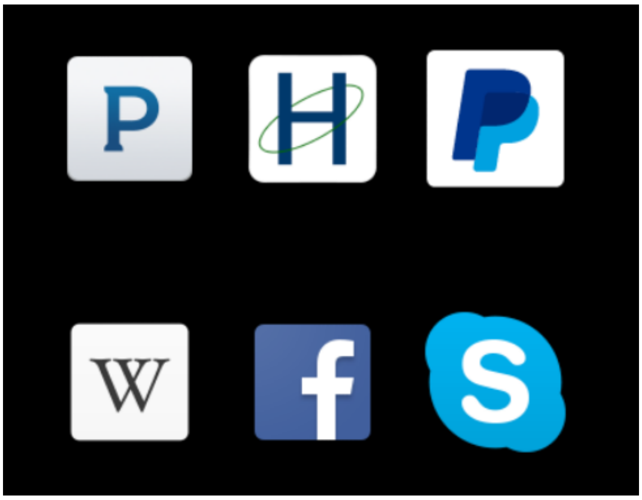


***Figure 10:** Icons for Pandora, Helios, Paypal, Wikipedia, Facebook, and Skype.*

When designing the Helios logo, there was a period of confusion because Google's logo did not match its own style guide in all cases. Figure 11 shows the two most recent Google logos. The highlights and shadows on the top image, along with the serifs on both fonts and the thin portions of the font do not match *Material Design* guidelines [53]. But on September 1st, they unveiled new compliant branding [78].

The new logo (Figure 12) contains many optimizations for mobile viewing. It has heightened visual weight and uses a consistent line thickness, which increases legibility when displayed on small screens. An entire font was created for the logo, Product Sans. This means that this logo and all other google logos can be rendered using text instead of images. This reduces bandwidth requirements and merges the visual styles of browser and mobile web pages, which were previously distinct [78].This change is evidence of the importance and appropriateness of the styles reported here.

Figure 11: *The two most recent Google logos, which were both in use on different web pages until Sept 1st 2015. The lower flat image was used in most cases, but as late as August 24th the upper image was still being used on google doodles, a popular portion of the website [79].*

Figure 12: *New google logo introduced on September 1st 2015*

§ 2.2 Structure

Android apps are made primarily of activities and fragments. An activity provides a screen that accepts interactions. Each activity gets its own window, which normally fills the screen, but may float over other windows. A fragment represents a behaviour or part of a user interface. It must exist within an activity, and multiple fragments may be shown at any time. Fragments have their own life cycle and handle their own input events. Fragments make it easier to design an app with different layouts for different size screens. An example of this is shown in Figure 13. Although Helios currently uses the same layout for every screen size, an emphasis on using fragments will make future layout design easier.

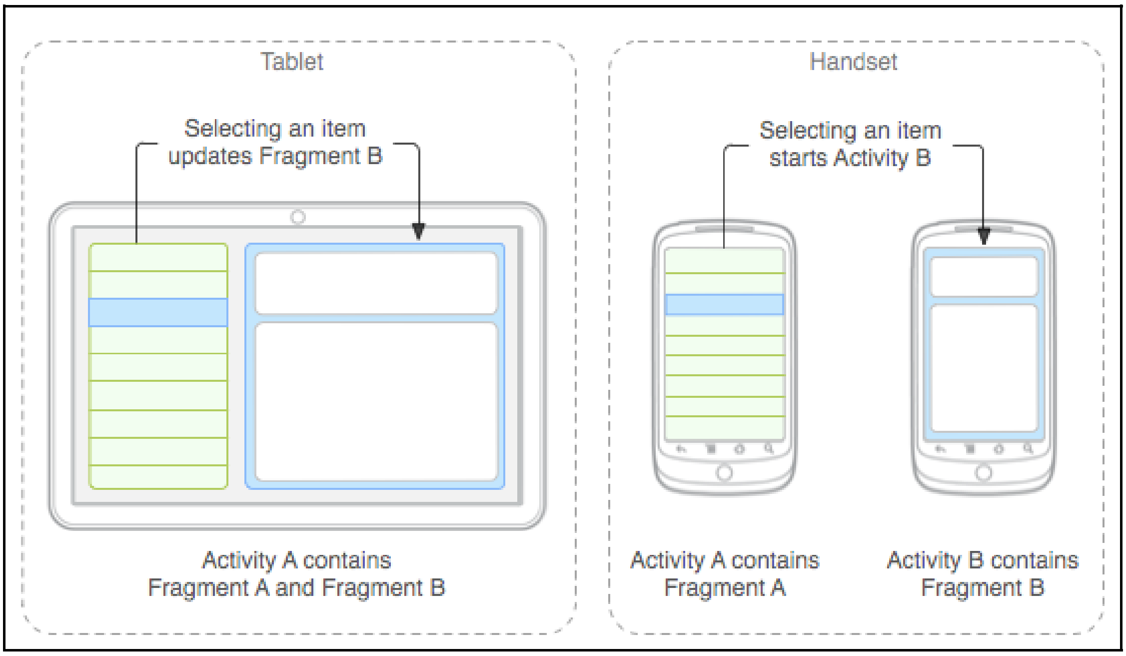


Figure 13: *"An example of how two UI modules defined by fragments can be combined into one activity for a tablet design, but separated for a handset design. [80]"*

The structure of Helios and the data flow between various components is shown in Figure 14. `MainActivity`[1] handles most of the work. Normally, it has one fragment that fills the whole screen. It can also create a navigation drawer fragment on top of the primary fragment by swiping from the left edge of the screen or clicking the navigation drawer icon (three horizontal bars). For each utility, it creates new fragments and they replace the welcome fragment in its container. Similarly, the reference fragments create new topic fragments which replace themselves in this container. The orientation, project details, and production fragments create dialogue boxes that float above the primary fragment container.

Due to the complexity of interacting with the the camera and the change in orientation from portrait to landscape, the camera and shade utilities are their own activities without navigation drawers. They can still be exited by pressing the back button (as can the other utilities). Important information is reported from the fragments back to `MainActivity` using `interface` and `callback` methods. Pertinent information is passed along by putting it inside a `bundle` when fragments are created. Each utility is explained in the following sections.

1 When using terms directly from the source code or referring to a specific class or method, `monospaced` font is used. When talking about informal groups of fragments, normal font will be used e.g. `Welcome` fragment vs. Welcome screen.

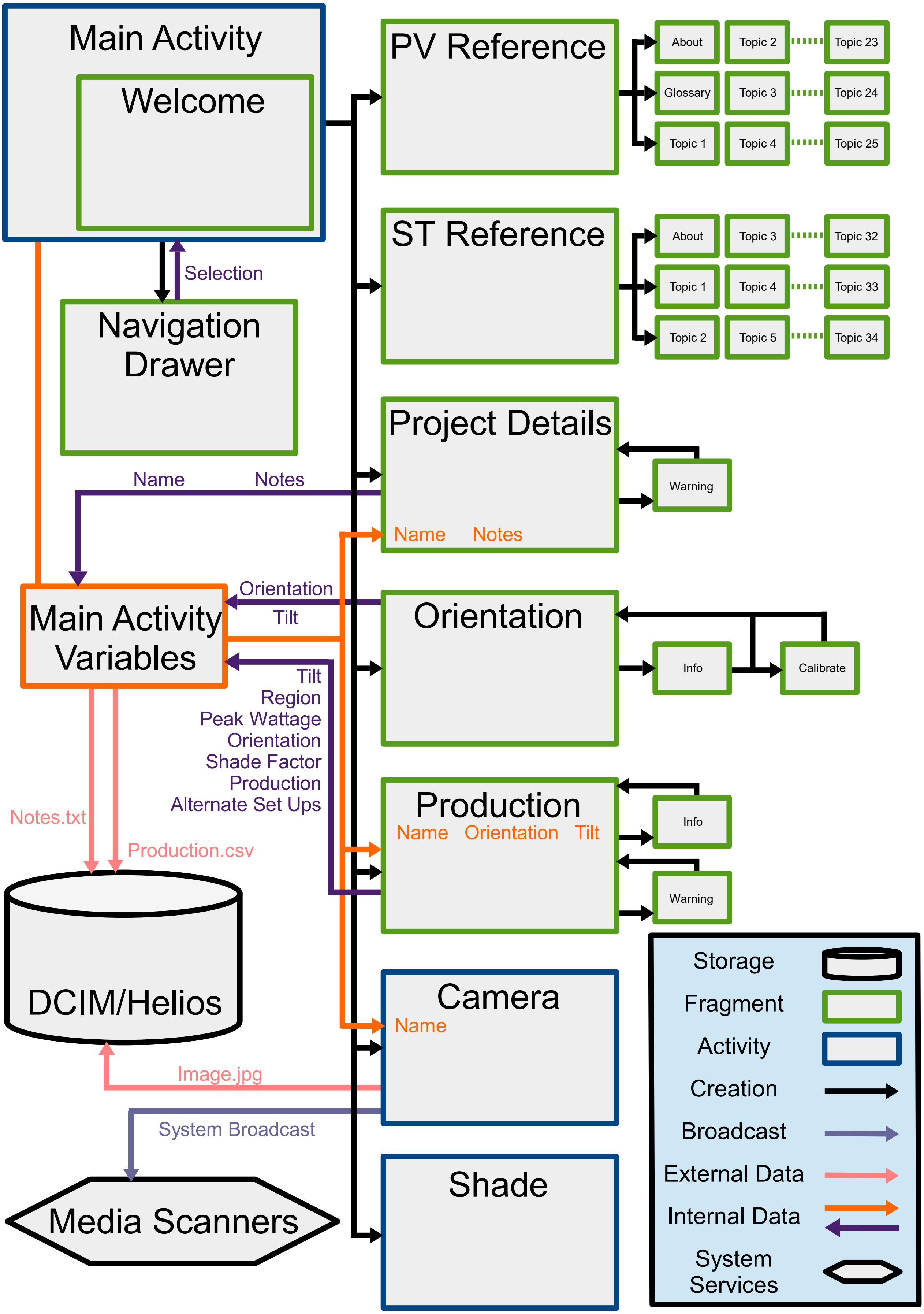


Figure 14: *Diagram of app hierarchy and data flow.*

§ 2.3 Welcome Screen

Upon starting the app, `MainActivity` creates a navigation drawer fragment and a `Welcome` fragment. The `Welcome` fragment contains the full Helios logo to help establish the app's identity. The first time the app is launched, the navigation drawer is opened automatically to show the user that it exists and the navigation options that are available. This is a natural way of learning how to reach different utilities within Helios. After the first launch, the shared preference `PREF_USER_LEARNED_DRAWER` keeps track of the fact that the user has learned about the drawer and it does not automatically open on future launches. Figure 15 shows the welcome screen and Figure 16 illustrates the navigation drawer.

Figure 15: *The welcome screen greets the user when starting the app. It also is the last thing they see if they exit the app using back navigation.*

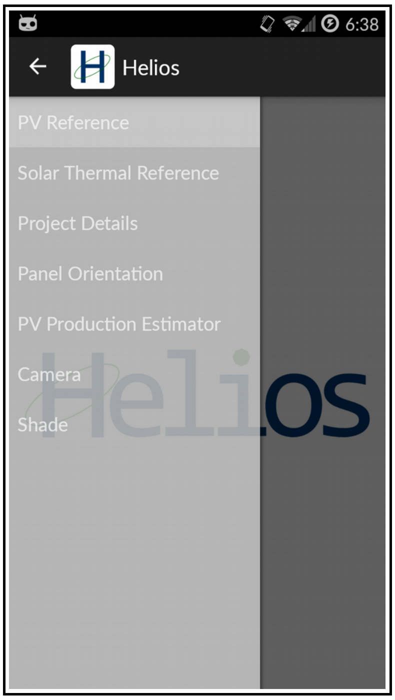


Figure 16: *Open the navigation drawer by swiping right from the left edge of the screen or click the three bars next to the launcher icon (not shown).*

§ 2.4 Project Details

Two pieces of information can be saved about the project or site survey in the Project Details utility, which is shown in Figure 17. The first is the name of the project. This is used as a prefix when saving or sharing any file within the app. The field restricts input to alphanumeric characters, space, underscore, and hyphen. When the user clicks save, it replaces spaces with underscores. These restrictions ensure that any entry is suitable for a file name prefix. The second field is for general notes and has no restrictions.

When this fragment is created, a `bundle` with the project name and notes is loaded. Their default values are "Default" and "", but reloading the fragment before `MainActivity` is destroyed will fill the text fields with the most recently saved name and notes. If the back button is pressed within the project details utility, a warning dialogue is shown to prevent the user from accidentally losing work (Figure 18).

Each field has a save button, which triggers a `callback` to `MainActivity` when clicked. They save their respective values to variables that can be sent to other utilities. Saving the notes also writes the notes to the `DCIM/Helios` directory in a text file named "`projectname_yyyy_MMdd_HHmmss_notes.txt`" where `projectname` is the project name and the rest is a timestamp generated at file creation. The `DCIM` directory is a standard location in Android used to store media files. The app checks to see if the `Helios` subdirectory exists and creates it if it does not.

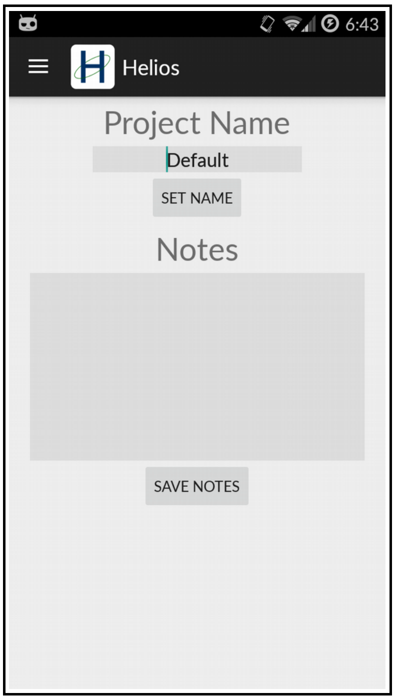


Figure 17: *Project Details utility.*

Figure 18: *When the back button is pressed, a warning dialogue appears to prevent the user from accidentally losing data.*

§ 2.5 Panel Orientation

§ 2.5.1 *Interface*

The utility interface is split into two sections: a compass with an orientation readout and a tilt readout. This can be seen in Figure 19. Both parts dynamically update by default. The markings on the compass spin around an arrow indicating which direction the roof should be relative to the phone. The user stands facing the installation site of the solar panels so that the panels would be facing the user. The device should be held horizontally, just like an analogue compass. The top section of the screen reads the angle between magnetic south and the the direction the panel is facing. Tapping the compass locks in the current reading and changes the orientation readout box to a green background to indicate that the measurement has been taken. Tapping again allows the compass to continue spinning and reverts the colour of the text box.

To measure the tilt of the installation site, the user may place the phone on the surface or line up the device with the surface by eye. This can be done with adequate accuracy by positioning the device so the user's eye, the long axis of the phone, and the roof are collinear. This measurement can be locked by tapping the bottom half of the screen.

The options menu contains an information button. It brings up a dialogue box (Figure 20) giving a brief description of how the utility works. It can be dismissed by clicking “Done” or additional info (Figure 21) can be viewed by clicking “Calibrate.”

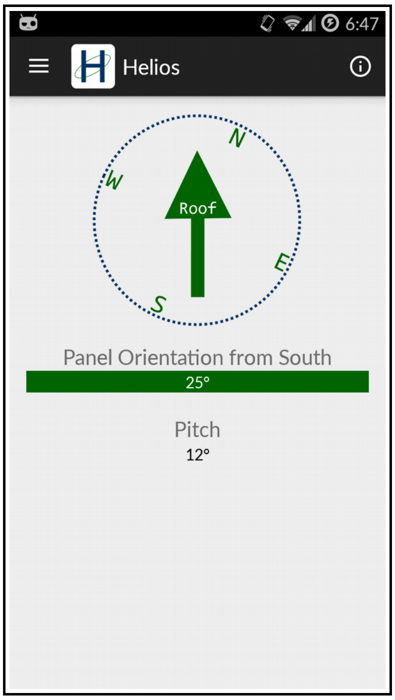


Figure 19: *Panel Orientation. In this screenshot, orientation measurement is locked, but pitch is not.*

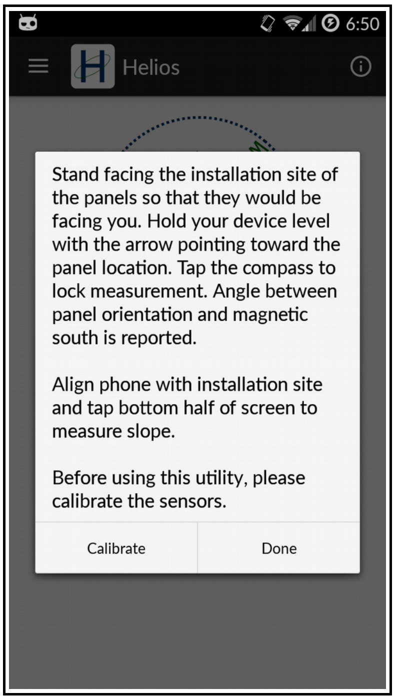


Figure 20: *Dialogue generated when the info button on the action bar is clicked.*

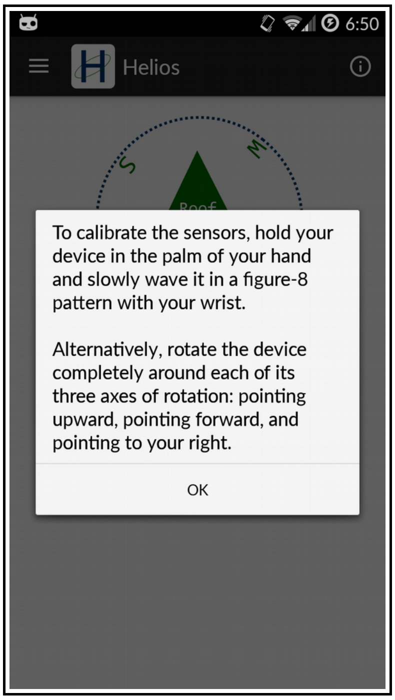


Figure 21: *Dialogue generated when the “Calibrate” button is clicked.*

§ 2.5.2 Back End

This utility allows the user to measure the pitch and orientation (degrees from south) of the proposed installation surface for solar panels. It uses the device's magnetometer and accelerometer to create a compass and a tilt meter. Most android devices have a magnetometer and a 3-axis accelerometer, but their presence should not be assumed. If this fragment is created on a device without an accelerometer, a `toast` will display saying "This device cannot measure tilt." A similar warning message appears if a magnetometer is missing.

This utility updates both the compass and the tilt display whenever `OnSensorChanged()` is called, which is automatically checked once sensor listeners are registered in the `OnResume()` method. The frequency of checking is set as `SENSOR_DELAY_NORMAL`, which is the slowest of the standard delays, since extremely quick response times are not needed. This is the same delay used to detect changes in a device's orientation (landscape or portrait) [82]. This saves system resources compared to a faster frequency. When sensors in an android device return values, they use the coordinate system shown in Figure 22.

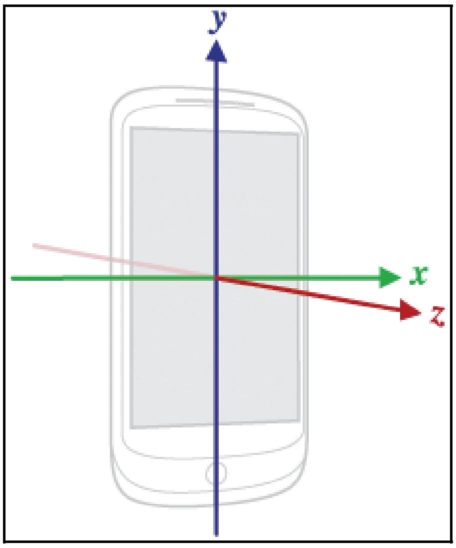


Figure 22: *Coordinate system of an Android system [81].*

The compass relies on both sensors. The readings from each are fed into `getRotationMatrix()`, which produces a matrix that describes the rotation of the device relative to an absolute coordinate system. The phone is aligned to this absolute system if y points to magnetic north and z points up from the surface of the earth. This matrix is then passed to `getOrientation()`, which produces an array with three values. They are azimuth, pitch, and roll. For this application, only azimuth matters, which is rotation about the -Z axis based on the earth coordinate system described above. This gives the measured angle from magnetic north. From here, it is simple to rotate the compass and calculate the orientation from south in degrees. For the code that updates the compass and pitch display, see Appendix D.

The accuracy of the compass on the HTC One Mini was checked against an analogue compass. The measurements normally agree with less than 10° difference. Rarely, the measurements are off by as much as 20°. Checking against dedicated compass apps, the error is consistent. This means its source is from the sensor itself and not the Helios code.

This issue appears and disappears with no apparent pattern and is not always constant in all directions. This may be due to magnetic interference from the environment or from within the device itself. Testing on the Sero 7 Pro started with very inaccurate readings, but they were correct within 10° after hardware calibration.

Measuring tilt only requires the accelerometer. The sensor reports the negative of the acceleration experienced by the sensor as a three dimensional vector using the phone's coordinate system (Figure 22) [81]. These readings are represented as g_{-z} and g_{-y} in Figure 23. If the phone has a constant velocity, the magnitude of this vector should equal the acceleration due to gravity.

For this utility, the value of interest is the angle between a plane normal to the gravity vector (horizontal) and the y-axis of the device. It is labelled θ in Figure 23. Once the acceleration vector is obtained from the sensor, values are normalized. This minimizes the effect of any non-gravitational acceleration. The angle between the y-axis and the horizontal is then arcsin(g_{-y}), since the vector magnitude (which is assumed to be g) is 1 after normalization.

When either measurement is locked by tapping the corresponding section of the screen, a `callback` to `MainActivity` is triggered. This sends the measured value to be stored in a variable in `MainActivity`. The values are put into a `bundle` and passed to the production calculator when that fragment is created.

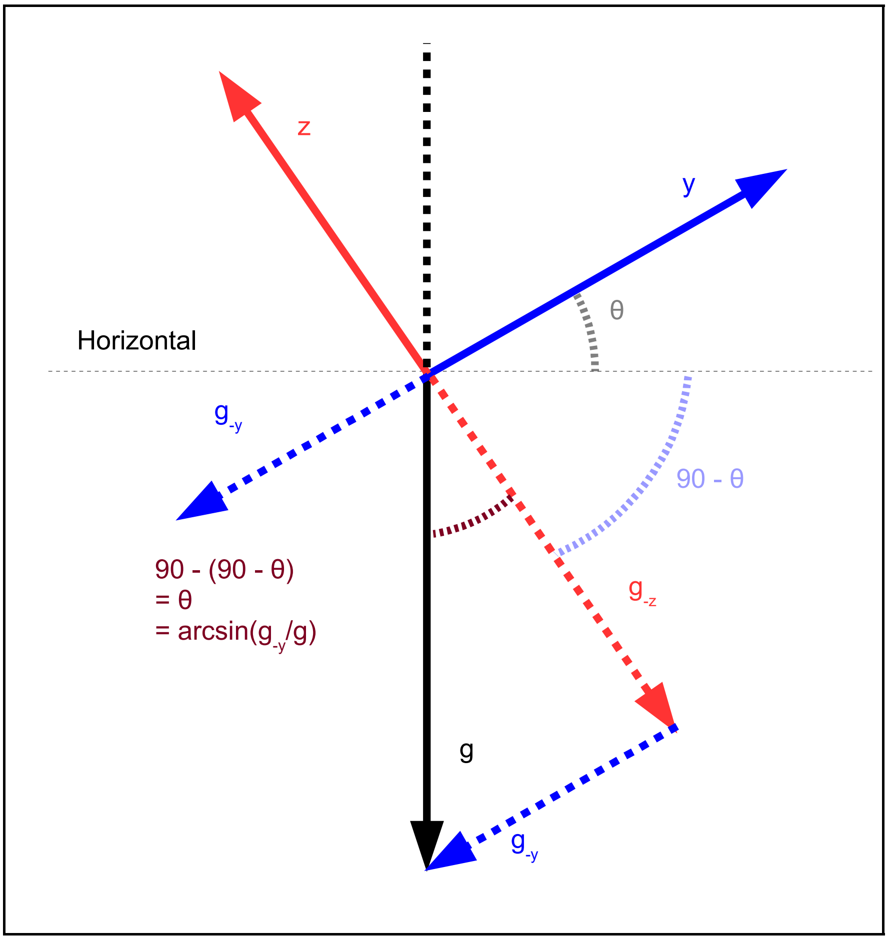


Figure 23: *θ, the angle of interest, can be calculated with arcsin(g_{-y}/g). The x-axis is not shown in this figure, but in this operation, gravity should have no effect in that direction since it is horizontal.*

§ 2.6 Photovoltaic Production Estimator

§ 2.6.1 Interface

The interface of the PV production estimation utility was designed to be as simple and safe as possible. When the utility is launched, the required variables are clearly displayed along with their default values (Figure 24). The user is greeted with a flashing cursor in the “Array Wp” field. This indicates that the field should be tapped and edited using the keyboard. Then, when the user taps on the remaining fields, a `spinner` (scrolling selection) dialogue appears. Using a `spinner` to select values eliminates the possibility of the user entering an unexpected measurement. This is especially important for the postcode field, because there is no standard format for the post code options. Even with 100 possibilities, a scrolling options menu is easy to navigate with a touch screen since a single quick flick can skip dozens of options at once. Finally, a large “CALCULATE” button displays the estimated annual production in kWh based on the entered data. A smaller section appears below that provides alternative pitch and orientation values to maximize production.

The options menu contains two options: share and information. The share functionality is described in the next section. The information button brings up a dialogue box (Figure 25) giving a brief description of how the calculator works. It can be dismissed by clicking “OK.” If the back button is pressed within the production estimator utility, a warning dialogue is shown to prevent the user from accidentally losing work (Figure 26).

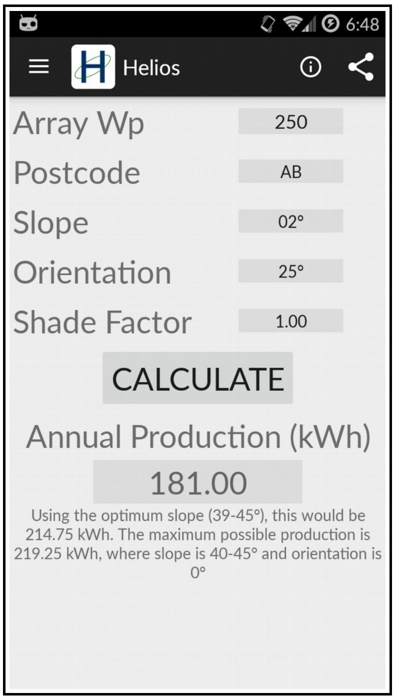


Figure 24: *The production estimation utility after calculations have been done.*

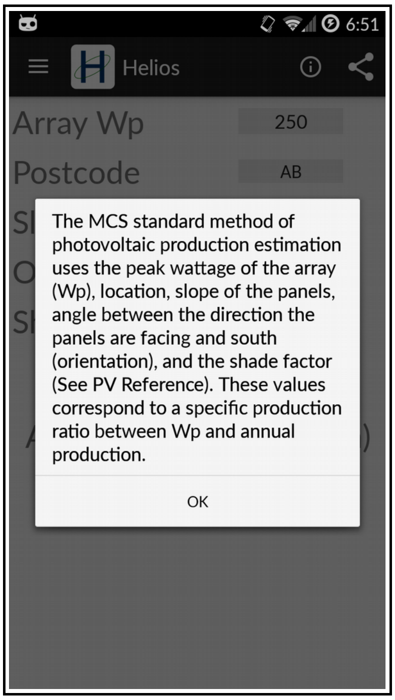


Figure 25: *Dialogue generated when the info button on the action bar is clicked.*

Figure 26: *When the back button is pressed , a warning dialogue appears to prevent the user from accidentally losing data.*

§ 2.6.2 Back End

Guide to the Installation of Photovoltaic Systems provides a standard method for estimating production [1]. First it uses the location, pitch, and orientation to find a ratio (Kk) between kWp and annual output in kWh. Then the estimated annual electricity generated (AC) is calculated using equation 1.

$$Annual\ AC\ output\left(kWh\right)=kWp\times Kk\times SF$$

Equation 1: *Determines annual production from peak output, a production ratio, and a shading factor.*

Peak kilowatt output (kWp) is the documented output at standard conditions (STC) summed across all panels in the array. The app requests this in peak watt output (Wp) to better accommodate smaller installations. The orientation is the azimuth angle relative to south rounded to the nearest 5°. Pitch is the angle between the panel and the horizontal rounded to the nearest degree. Shade factor requires a more detailed site survey, which is described in its own section. For now, the factor is entered into the app manually.

When the fragment is created, a `bundle` is made with three values: orientation, pitch, and project name. These may have the default values or be set from other utilities. These values determine the starting selections for each `spinner`. The tilt and orientation utility can measure an orientation between 0° and 180°, but the MCS method cannot accept values above 90°. To fix this, any orientation values above this limit set the starting orientation to 90°.

Location uses post code prefixes which map onto 25 regions of solar potential. A map of these regions is in Appendix E. A Microsoft Excel file supplied on the MCS website provides Kk values based on the region, tilt, and orientation [83]. In order to ensure quick access to the 40,500 data points in the spreadsheet, it was converted to an SQLite database and is packaged with the app. An online tool, *Convert Excel File To SQLite,* was used to do the conversion [84]. Since the columns and rows in the Excel table were named by orientation and pitch values, special attention had to be paid in the SQL Queries. The selected values are converted to strings before passing them into the queries, as numeric values throw an error. The code to calculate the production estimate, including the SQL queries, is in Appendix F.

The `SQLiteAssetHelper` helper class obtained from [85] was used to import the pre-made database that contains both the Kk ratios and a key to map regions to postcodes. Android supplies a class to generate the appropriate SQL query commands to organize and filter the database. A combination of returning specific orientation columns and sorting the data in descending order allows both specific ratios and ratios for maximum production to be read.

This database takes up 506KB of space, which accounts for 21% of the whole .apk file. It would have been beneficial if the ratios could be produced using a formula to reduce the app's size. Unfortunately, the ratios were created from weather station data. Several hundred stations around Europe provided the basis for the PV-GIS database that the ratios are derived from. Satellite images and interpolation techniques were used to make a complete table [86]-[88]. Since the ratios are based on data and not a model, a database is the only option.

Using sensors to set the location value was considered, but this was deemed unnecessary. Latitude and longitude measurements from a GPS signal would have to be converted into a postcode. To further complicate this, the postcode prefixes do not have a consistent style. For example, all NG postcodes are part of the same region, but CM21-23 is in a different region than the rest of the CM postcodes. Dedicating the required time to implement this feature would be unwise for this project's timescale. By entering the postcode manually, the app only relies on the user's knowledge, which is likely to be faster and more reliable than establishing a GPS signal in many situations.

After the production is calculated, a comma separated value (`.csv`) file is saved to the `DCIM/Helios` directory. The directory is created if it does not exist. This file can be opened as a text file or in any spreadsheet software (Figure 27). The filename is automatically generated in the form “`projectname_yyyy_MMdd_HHmmss.csv`” where `projectname` is the name set by the user and the rest is a timestamp of file creation. Using the project title allows the files to be easily organized. Incorporating a timestamp allows various estimates to be made without overwriting previous estimates. A `toast` is then shown with the entire file path to allow the user to find it easily.

H28:I30

	A	B
1	optimum_slope	36-42
2	production_with_optimum_slope	441
3	optimum_slope_for_south_facing_panel	37-42
4	max_production	446.5
5	slope_chosen	25
6	orientation_chosen	20
7	production_chosen	432.5
8	shade_factor	1
9	zone	11
10	kK_ratio	865
11	peak_watts	500
12		

Figure 27: *Example of a generated .csv file opened in a spreadsheet program. The data in this sheet has been transposed from the exported data to better fit in this space.*

It would be useful if all of these variables were available to any future utility that might be added to the app. Therefore, this saving operation takes place in `MainActivity` instead of the production calculator fragment. When the calculate button is clicked, a `callback` is triggered, which sends these values to `MainActivity` and writes them to file. This makes the variables accessible to any future utility that might need them by using a `bundle` or intent created in `MainActivity`.

In addition to saving the values locally, the user may also send the most recent estimate using Android's standard share function. The share icon provided in the Android developer's resources is added to the options menu. When it is clicked, Helios checks to see if a production value has been calculated. If not, a `toast` is displayed requesting that the user perform a calculation. Otherwise, a `sharingIntent` is launched with a `text/plain` MIME type. This informs the operating system that the user would like to share a text file. A dialogue appears listing all apps installed on the user's device that can receive a `text/plain` share intent such as gmail or google drive. The last saved `.csv` file is the body, and the subject is “`projectname_yyyy_MMdd_HHmmss.csv`”.

This allows the site information to be exported when connected to any data network or even through an SMS. This data can then be read by Sasie's new Excel based financial analysis program that was designed by a different researcher. The ability to tailor both pieces of software to work well with each other can streamline the entire surveying process.

Originally, the dash in the optimum slope ranges was an en dash (–), which typically looks better in print and on screen than a hyphen. “`\n`” was used to create the new line that separates the variable names from their values. When opening the `.csv` file using Windows notepad, the en dash showed up correctly, but the entire document was a single line. Since different operating systems use slightly different notation for line breaks, this was not completely unexpected. Microsoft Excel, however, recognized the line break, but did not render the en dash correctly. It showed up as “â€.” This was solved by replacing the line break character “`\n`” with “`\r\n`” and the en dash with a hyphen (-). The hyphen is a standard character, so it should show up correctly on any system. Adding “`\r`” to the line break adds a carriage return command. Between the two commands, most systems should recognize at least one line break.

Multiple sample results from this calculator were confirmed by hand calculation and manual table lookup. Samples were taken from a variety of slopes, orientations, shade factors, and regions. In addition to the annual productions, the optimum values displayed in the additional paragraph were tested as well. In every case, the manually calculated values matched the app's values exactly.

§ 2.7 Camera

This portion of the app is designed to document the visual properties of an installation site. Built as a stepping stone to the shade measurement utility, it came to be a utility of its own. It it a simple landscape camera that contains only a shutter release button (Figure 28). When it is pressed, a custom `View` covering the entire screen momentarily flashes a highly transparent white to indicate a picture has been taken. Its strength is that it saves the pictures in `DCIM/Helios` as “`projectname_yyyyMMdd_HHmmss.jpg`.” This naming convention keeps the images organized by project name within the `Helios` media directory.

After saving the file, a system broadcast must be sent out that indicates that new images have been saved to the device. Any installed apps listening for this type of broadcast will receive it and act appropriately. Most gallery apps, for instance, will create a thumbnail of the image and display it in its library. This will organize any captured images into a Helios directory within the gallery app, which can then be edited and shared like any other image.

Figure 28: *Screenshot of the camera utility.*

§ 2.8 Shade Measurement

The share measurement utility is not finished, but initial work on a utility to measure the shade factor according to MCS guidelines (§ 16.20) has been completed. Currently, the utility only consists of a camera `Preview` and an overlay displaying the pitch and direction that the camera is pointed (Figure Error: Reference source not found). When the utility is completed, these values can create a cursor for creating horizon lines on a sun path diagram (Figure 30). As the horizon lines are drawn, they will remain on screen and move along with the camera background as an overlay. This movement can be achieved by requesting the camera's angular field of view and figuring out how much of this is shown on screen at once. Once this is known, the overlay can shift in the opposite direction that the phone moves.

Figure 29: *Screenshot of current shade measurement utility. Angle from horizontal is displayed above the white line, and rotation angle from north is below the line.*

The horizon lines would be checked against the sun path diagram pixel by pixel to determine which segments have shade in them. In order to overcome the long calculation time plaguing *Solar Shading* as noted in Table 2, the horizon lines could be low resolution. Since the sun path diagram consists of only 100 segments which are geometrically simple, it can be accurately mapped with resolution at least as low as 150 x 64 pixels (Figure 31). Additionally, the algebraic expressions for curves approximating those on the diagram could be determined, which could speed up processing by splitting the image into different sections for analysis.

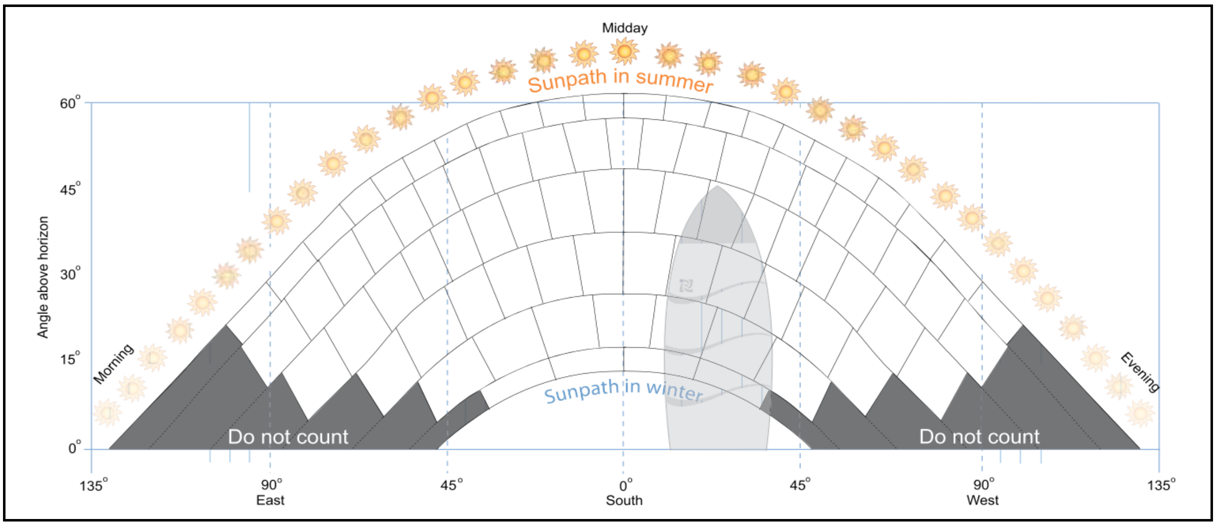


Figure 30: *MCS sun path diagram [1]. An example horizon line is drawn on it.*

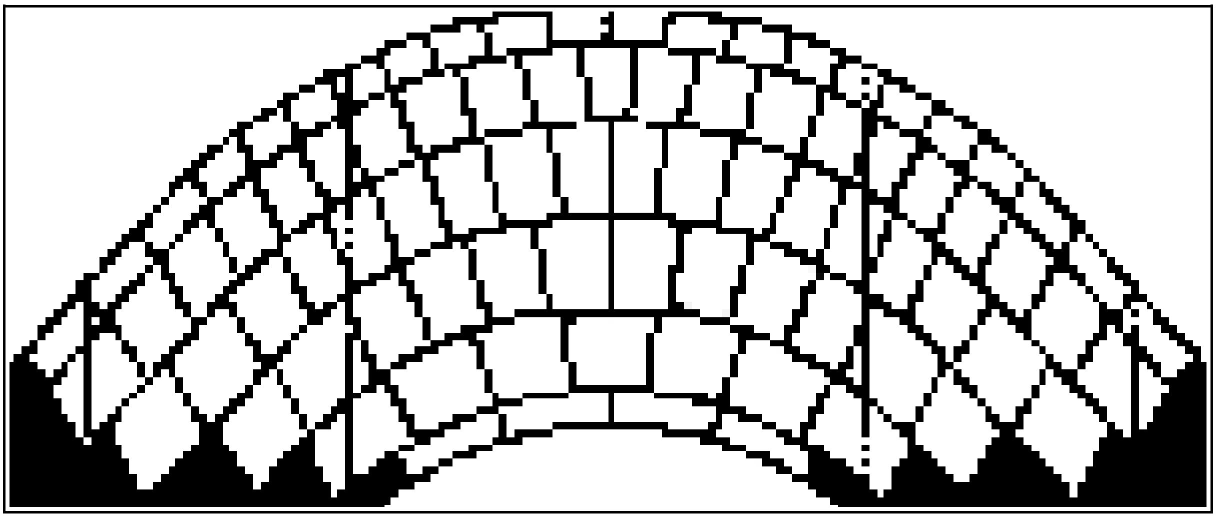


Figure 31: *150 x 64 pixel MCS sun path diagram.*

§ 2.9 Best Practice Guides

Two best practice guides were made based on the two most popular domestic sustainable energy solutions in the UK: photovoltaics and solar thermal hot water. They are each their own utilities in the navigation drawer. The content of each guide is taken from the documents listed in Table 1.

Document	Original Word Count	App Word Count
Photovoltaic Guide	27,000	7,600
Solar Thermal Guide	19,000	9,100

Table 4: *Word counts from original documents and final app content.*

The text from the PDF files was copied into a word processor. From there, the content was edited to condense wording, remove redundant phrasing, and take out the information least pertinent to installation procedures, such as commissioning details. Also, sections were split, merged, and rearranged to provide clearer divisions between topics and make them a suitable size for phone navigation. Topics range from 40 to 900 words, and most are around 350 words. Where deemed most useful, tables and diagrams were copied and included. See Appendices G and H for the complete content of the edited guides. The word counts of the original PDF files and the text of the guides are shown in Table 4. A large amount of the reduction came from removing things like the index, large tables, and example forms.

Next, the rich text had to be converted into a format that can be shown within the app. HTML tags, system commands, and XML replaced the existing formatting. Special characters were replaced with unicode identifiers, which produce the special characters when rendered on screen. Examples of these formatting marks are in Table 5.

HTML	
 	Bold
<i> </i>	Italics
	Subscript
Linux Commands	
\t	Tab
\n	New line
Unicode	
\u00B0	°
\u00B2	²
\u00D7	×

Table 5: *Examples of formatting commands used throughout Helios.*

Each topic is its own fragment since the layout varies among them. They have at least one section each, and sections are separated by a title and a horizontal ruler. As an example, the XML from the photovoltaic glossary fragment is in Text Box 3. The actual information is contained in a resource string. This is the recommended method of showing text, since it minimizes the XML code and puts as many strings as possible in one location to ease localization.

Creating bullet lists proved to be a challenge. One option is to use a unicode bullet symbol and then follow it with a string. However, if the string is rendered to be more than a single line, the second line is not indented like one would expect from a bulleted list. A `spannable` can be used to get around this. A `spannable` is a character sequence that allows formatting control on a character by character basis [89]. One type of `spannable` is a `BulletSpan`, which can build an appropriately formatted bullet list from a character sequence. A custom class was used that takes as input the leading margin and as many strings as required [90]. It turns these strings into character sequences and does the appropriate formatting. Then it returns a bulleted list with each item being one of the strings passed to it as an argument. This list is a single string that can be set to the contents of a `TextView`.

The two best practice guides are listed separately in the navigation drawer. When a guide is accessed, a `ListView` appears. A `ListView` makes a scrollable list of objects, where each object shares an instance of the same fragment, but they are populated by different information. In this case, each object is a simple `TextView` filled with one item from a list of topics (Figure 32). By clicking on an entry, a new fragment is loaded containing the information about that topic (Figure 33). The topic list is in alphabetical order preceded by an "About" page that explains the origins of the information and a disclaimer. The photovoltaic guide also includes a glossary directly below the "About" entry.

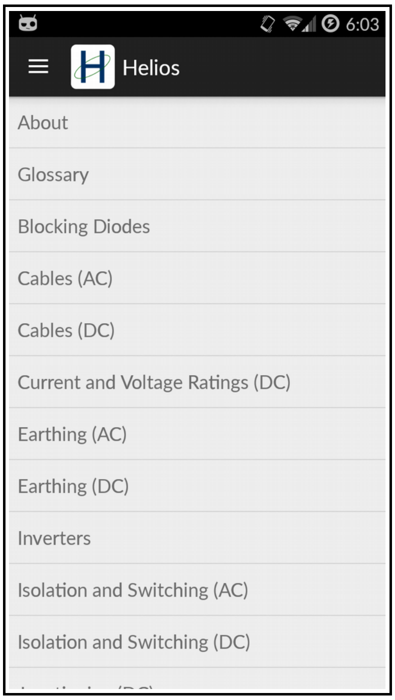


Figure 32: *Topic selector for photovoltaic guide. Clicking an item brings up information.*

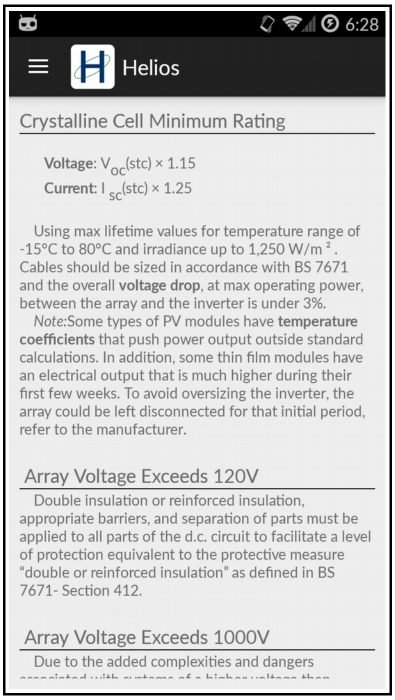


Figure 33: *Example of information fragment, Current and Voltage Ratings (DC).*

```
  <LinearLayout xmlns:android="http://schemas.android.com/apk/res/android"
      xmlns:tools="http://schemas.android.com/tools"
android:layout_width="match_parent"
      android:layout_height="match_parent"
tools:context="com.example.mk.helios.pv_glossary" android:orientation="vertical">

      <ScrollView
          android:layout_width="fill_parent"
          android:layout_height="fill_parent"
          android:padding="10dp">

          <LinearLayout
              android:layout_width="fill_parent"
              android:layout_height="wrap_content"
              android:orientation="vertical">

              <TextView
                  android:layout_width="wrap_content"
                  android:layout_height="wrap_content"
                  android:text="Glossary"
                  android:id="@+id/textView"
                  android:textSize="@dimen/textheading" />

              <View
                  android:layout_width="fill_parent"
                  android:layout_height="1dp"
                  android:background="#000"/>

              <TextView
                  android:layout_width="wrap_content"
                  android:layout_height="wrap_content"
                  android:text="@string/pv_glossary"
                  android:id="@+id/text1" />

          </LinearLayout>

      </ScrollView>

  </LinearLayout>
```

Text Box 3: *XML from the photovoltaic glossary fragment, the simplest possible reference topic fragment.*

§ 3 Google Play Analysis

§ 3.1 Submission Requirements

Helios can by analysed using Google Play standards to determine if it is publication quality. A launch checklist is provided on the Android developer website that outlines the steps to submit an app to the Play Store [91]. The names of each step are listed below. The steps marked in green are actionable now and are addressed below.

1. Understand the Publishing Process†
2. Understand Google Play Policies and Agreements†
3. Test for Quality
4. Determine your App's Content Rating
5. Determine Country Distribution
6. Confirm the App's Overall Size
7. Confirm the App's Platform and Screen Compatibility Ranges
8. Decide Whether your App will be Free or Priced*
9. Consider using In-app Billing or Android Pay*
10. Set Prices for your Products*
11. Start Localization
12. Prepare Promotional Graphics, Screenshots, and Videos*
13. Build and Upload the Release-ready APK
14. Plan a Beta Release*
15. Complete the Apps' Store Listing*
16. Use Google Play Badges and Links in your Promotional Campaigns*
17. Final Checks and Publishing†

Text Box 4: ** indicates steps that will change depending on future relations with Sasie. † indicates steps that are just reading and double checking. Green indicates steps that can be addressed now.*

§ 3.2 Test for Quality

The app should conform to a list of quality assurance measures. They are listed on the developer website along with specific tests to check the requirements [92]. A complete list of these requirements and Helios' results are in Appendix I. There are four categories of requirements: visual design and user interaction, functionality, performance and stability, and Google Play. Currently, Helios passes every test in visual design and user interaction as well as performance and stability.

Three requirements within the functionality category refer to screen orientation and changing between orientations. They are listed in Table 6. Helios does not pass these tests since it locks the user into portrait orientations for most utilities and it forces landscape mode in the camera activities. It does not pass, but it should not be considered a failure either, because there is reason behind forcing these orientations. The camera activities are intended for use taking pictures of installation sites and mapping the horizon. Only landscape mode makes sense for that. The best practice guides are read, which is natural to do in portrait orientation. In the future, alternate layouts can be made, but for now Helios forces specific orientations.

UI and Graphics	App supports both landscape and portrait orientations (if possible). Orientations expose largely the same features and actions and preserve functional parity. Minor changes in content or views are acceptable.	CR-5
	App uses the whole screen in both orientations and does not letterbox to account for orientation changes. Minor letterboxing to compensate for small variations in screen geometry is acceptable.	CR-5
	App correctly handles rapid transitions between display orientations without rendering problems.	CR-5

Table 6: *Screen orientation quality measures [92].*

Some of the other requirements cannot be fulfilled at this time because they refer to marketing materials. Marketing is not a step that has been reached in Helios' development. The only major concern is the intellectual property of the best practice guides. As stated previously, they are each based on a single source. Although proper attribution is enough for academic purposes, that is often not enough for commercial situations.

The copyright statement in *Guide to the Installation of Photovoltaic Systems* states,

> "MCS as copyright owners assert their moral rights to be recognised as authors of this work with support and assistance from the MCS Solar PV Technical Working Group. Limited licence is given to reproduce images, text and graphics in any medium wholly or in part for information or research only on condition that the copyright is acknowledged and that reproduction is made without charge to any recipient.[1]"

Such attribution is provided within the "About" page of the photovoltaic reference guide. As long as that section of the app is provided for free, then there these terms for reproduction have been followed. A similar statement does not exist within *Solar Water Heating Systems – Guidance for Professionals, Conventional Indirect Models.* But the document is no longer distributed by the Energy Saving Trust and it was originally distributed for free. It may be necessary to reach out to Energy Saving Trust, or do a re-write of the guide. For now, Helios will be used only by Sasie employees and will not be publicly distributed, which makes this a non-issue.

Enabling `StrictMode` creates a list of best practice rules that the app is tested against as it runs. If the app violates any of these rules, a dialogue pops up on the device and a log message describes the violation. The first time running this test violations were found when the SQLite database was read; when leaving the production utility before the SQLite `cursor` was closed;and when notes, production values, and pictures were saved to disk. These read/write operations were being carried out on the UI thread, which should not be done.

By default all code runs on the UI thread. The UI stops responding while code is running. This is designed for near instantaneous actions. This becomes dangerous for things like retrieving data over a network or reading/writing a file to disk. Even if reading/writing normally takes a fraction of a second, as it does in Helios, background processes can still slow down disk access. To prevent the UI freezing, these actions should be done on a background thread.

This can be solved by moving these processes inside of customised `AsyncTask` classes. An `AsyncTask` is made of three parts, `onPostExecute`, `onPreExecute`, and `doInBackground`. The first two run on the UI thread and can be used to ensure certain UI events happen, like updating a loading bar or showing a `toast`. Any code in `doInBackground` is done in a background thread, which is where the read and write operations need to be.

After placing each of these operations in an `AsyncTask` and closing the SQLite `cursor` immediately after the queries are finished, the `StrictMode` violations are not triggered anymore. Two other violations still trigger, but one is from stock code generated by Android Studio and the other is within a standard class. The first is when the navigation drawer shared preference is read, and the other involves the `sharingIntent`. Since these are from official sources, they should be safe.

§ 3.3 Determine your App’s Content Rating

Google Play filters apps into the four categories below. When a user browses the store, filters are put in place to only show apps of certain content ratings. This protects young users from accessing inappropriate apps and it also gives the user an indication of what to expect from the software [91].

- Everyone
- Low maturity
- Medium maturity
- High maturity

Helios does not contain violence, sexuality, strong language, or references to controlled substances. It does, however, request permission to use device location (accelerometer and magnetometer), which bars it from having an “Everyone” rating. Therefore Helios is expected to earn a “Low maturity” rating. The rating is based on a questionnaire within the developer console, which requires a $25 registration fee. Since Helios' publication future is uncertain, a developer console account has not been created.

§ 3.4 Determine Country Distribution

Most features in Helios are designed for the UK market. The best practice guides are based on MCS and IET regulations, which only apply in the UK. Similarly, the photovoltaic production calculator requires a UK postcode to work. It is most appropriate for Helios to be restricted to the UK market.

§ 3.5 Start Localization

Since the app was created using English(UK) and its distribution will be limited to this country, no localization is required. If development continues, Helios can be split into different version branches designed for other countries.

§ 3.6 Confirm the App's Overall Size

The size limitation for an app on the Google Play store is 50MB. It may also have up to two expansion apk files of 2GB each [91]. The size of the Helios .apk file is 2.35MB, which is is well under the 50MB limit.

§ 3.7 Confirm the App's Platform and Screen Compatibility Ranges

Setting the minimum API to version 15 (Android 4.0.3-4.0.4, Ice Cream Sandwich) will allow Helios to run on 95.1% of active android devices based on the data in Figure 3 [27]. . Although designed for the most recent Android version (API 22), compatibility libraries guarantee that it will work at least as far back as Ice Cream Sandwich. The user interfaces within Helios are designed to work on phones and tablets of all sizes, but Android Wear and TV form factors should be restricted.

Helios was tested on five different devices. They are listed in Table 7. They span screen sizes from small to xlarge, densities from ldpi to xxhdpi, and API from 15 to 22. Due to adaptive XML layouts, the ability to scroll, and app compatibility libraries, Helios worked without problems on all of these devices. Ideally, the text, buttons, and fields would be larger on the Nexus 10 than what was found during testing, but this did not affect the functionality of the app. Although this should be improved upon, it is not enough to restrict xlarge devices.

Device	Type	Screen Size	Density	API
HTC One Mini	Hardware	4.3”, normal	341, xhdpi	19
Sero 7 Pro	Hardware	7”, large	216, tvdpi	22
Nexus 5	Emulator	5”, large	445, xxhdpi	22
Nexus 10	Emulator	10”, xlarge	365, xhdpi	22
2.7” QVGA	Emulator	2.7”, small	148, ldpi	15

Table 7: *List of devices Helios was tested on.*

§ 4 Other Considerations

§ 4.1 Sasie Ltd.

Throughout the project, communication with Sasie was very light. The only employees that were in contact were Mo Kelly and Jill Holland. An initial meeting on April 20th 2015 was an explanation of the initial project: assembling multiple best practice guides for publication. After informing them of previous publications and the switch to developing an app, no productive information was obtained until a meeting on August 17th 2015. At this point, the existence of another researcher developing an Excel based financial analysis tool was made known. This meeting resulted in data export being moved to a high priority in order to interface with this financial tool. Also, the need for a good solution to measuring shade levels was established.

All development and testing was done on personal hardware. No advice on the technical, visual, or informational contents of Helios was provided by Sasie employees past the initial meeting about best practice guides. Discussion of shading measurements and data sharing was already planned, they just gained increased priority after the August 17th meeting. In a meeting on the 7th of September, Mo Kelly and Jill Holland made their intentions clear to continue development and hire the author in some capacity [93].

§ 4.2 Hardware Limitations

When any app utilizes device sensors, the user must always be aware of the dangers of trusting them completely on any device. Certain sensors, such as accelerometers and gyroscopes, are usually accurate. With some sensors, such as cameras and GPS, it is normally obvious when something is not working right. Other sensors, however, especially the magnetometer, make it harder to detect inaccuracies. Before using this for professional surveying, it is highly recommended to ensure that reliable measurements can be made. This can be done by comparing the app's measurements to a trusted source after performing calibration. Information on hardware calibration is given in the orientation utility, and software based corrections can be added in the future.

Installing a magnetometer inside a cramped electronic device invites interference, especially considering the wide range in quality of Android devices. Also, a sensor installed in an unexpected orientation can change measurements drastically if it establishes a non-standard coordinate system. In all cases, the user should use good judgement when taking measurements with any electronic device, especially on multi-purpose platforms like an Android phone or tablet.

§ 4.3 Monetization

There are multiple ways to generate income from an app. They include:

- Paying for the app outright
- In-app purchases
- Advertisements
- Subscription fees

Due to the copyright on the photovoltaic reference guide, that material cannot be sold. The guides would be distributed freely, but ads could be placed on the pages. From there, adds can be placed on other parts of the app, or they could be premium features bought one at a time or part of a package. If Sasie decides to create a professional software suite, then the best option would probably be subscription licensing. A fee would guarantee the user access to the software, updates, and some level of support for a period of time.

§ 5 Future Work

> "You may think using Google's great, but I still think it's terrible."
> - Larry Page, CEO of Google

Text Box 5: *At Wall Street Journal's D Conference in 2003, Larry Page touched on the need for constant progress [94].*

Helios is ready for a public launch, but there are still many features that would make it a stronger app. Some have been mentioned throughout this report, such as finishing the shade measurement utility. Other utilities could centre around wind loading, solar thermal sizing, and photovoltaic panel and inverter libraries. Technical work could increase accuracy by incorporating additional sensors. Additional settings could allow data to be exported for use in other pieces of software such as RETScreen.

Installing solar panels on a roof requires careful consideration of the additional wind forces generated by the altered roof geometry. Calculations are based on the Eurocode and the process is addressed in the photovoltaic guide. For some roof types, a calculator utility would be useful, although in other cases a structural engineer must be consulted. For simple roof geometries, a dedicated calculator would speed up the process.

Similarly, a calculator could be used to help size a solar thermal water heating system. Consultation with Sasie would be required to determine their specific methodology. On a base level, these calculations require little more than the number of people and water using appliances in a household. But a useful professional sizing utility would have to incorporate a list of commonly used panels and storage tanks and it would have to include the properties of the roof and location.

Helios already includes a photovoltaic production estimator, but this can be extended to incorporate the details of the solar panels. By specifying the specific panels used, the electrical characteristics of the array can be determined. From there, an inverter can be recommended. Like the solar thermal sizing utility, this would require a list of Sasie's commonly used panels and inverters along with their technical specifications.

In different parts of the app, the magnetometer, accelerometer, and camera sensors are used. These are some of the most common sensors on android devices, but using other ones could increase measurement accuracy. Adding a GPS option could automatically detect the region for solar calculations, and it could change the orientation measurements from being based on magnetic north to true north. More advanced sensors such as a gyroscope could work in tandem with the currently used sensors to make the pitch measurement and the eventual shade survey utility animate more smoothly.

The current format of exported data can be read by any text editor or spreadsheet program, but this can be improved upon. The financial tool recently developed by Sasie will be updated by this author to automatically accept Helios formatted data and use it to fill in the relevant fields. If Helios become popular enough, it might be beneficial to allow exporting data in other formats as well. This can be done to ease the transfer of data between Helios and popular pieces of analysis software such as RETScreen. This could increase its audience significantly.

§ 6 Discussion

The properties of a successful app along with trends in modern design were discussed in § 1.3 . Helios is *useful*, because it fills a void in the market. It will be the first app on the Google Play store that explicitly uses MCS methodology to calculate photovoltaic production. It will also be the first to export data in a way that can be directly read by a spreadsheet. Lastly, it will also be the first to contain professional sustainable energy reference documents. Its usefulness will only increase as more features are added.

It has high *usability*, because it is easy to learn and use. Users will be familiar with the use of a navigation drawer and share icon from some of the most popular apps, the ones developed by Google. The information icon (“i” inside a circle) has been a standard on many platforms and the specific icon is in the core Android icon set. Pictures are handled the same way the user handles any other photos they take, since they are saved to the phone and added to any media galleries the user has through a system broadcast.

The app is *desirable*, because it follows the design trends of popular apps and *Material Design.* The flat and simply coloured graphics invoke a familiar digital environment. It is also designed to avoid negative emotional reactions that arise when a device cannot get a signal or loads slowly. This is done by making the content entirely native. At this point, Helios stores all data within the app and does not rely on any signal, even GPS.

Lastly, Helios is mostly *safe*. Navigation can be reversed at any time by using the back button with warning dialogues if there is a risk of losing data. The ability to reopen data once it has been saved would make it even safer and more useful. Currently, when the app process is destroyed, it is impossible to open saved data from within the app, although it it saved to disk and available via a file explorer.

The immediate future of this app will be for use exclusively within Sasie by their engineers [93]. If they decide to release this software after the initial internal use, it can become become a strong competitor as a tool in the industry. From conversation with Mo Kelly of Sasie, there does not appear to be a standard software suite for this in the UK [95]. One of the services they provide as a company is installer training. If they develop their own software suite that includes this app for field work plus a more complex financial analysis tool for the office, they can teach it to anyone they train.

§ 7 Results & Conclusion

After the initial research, it took a period of six weeks to go from having never touched Java before to having a publication ready Android App. There is still much more that can be added, but this is true of nearly all software. The source code, .apk file, and a video of the app is available in Appendix J.

The minimum goals set forth in § 1.1.3 were all met. Only one of the nine additional goals was met (production estimation utility), but goals changed as the project progressed. The purpose of Helios moved from being a reference app to a tool to help professionals during site surveying. In light of this, the following objectives were set and delivered.

Further goals:

1. Save production data in a `.csv` file
2. Export production data using Android share function
3. Tool to measure panel tilt and orientation
4. Ability to save notes about installation site
5. Camera for documenting site

After examining the Google launch checklist in Section 3, it is clear that Helios is ready for launch. A beta release would be wise to begin with, but without major unforeseen problems on other physical devices a full release would require very few changes. A greater influence on the app's publication future will be the type of relationship that is created with Sasie and how they want to proceed. After the addition of financial tools, they plan to use Helios as an internal tool only [93]. Of course, this can change in the future.

Sustainable energy installers typically rely on a sales team to initiate a transaction and then engineers to confirm the system details. Mo Kelly sees Helios as a way to merge these positions [93]. By merging measurement tools and financial analysis in one mobile platform, a single engineer can greet a customer, survey the location, and provide a detailed cost breakdown before they leave the premises. This is a time of rapid advancement in both energy systems and mobile electronics. High energy density batteries have allowed the revolution of ever more powerful smart phones, so it only makes sense to wield that power to facilitate the spread of sustainable energy solutions.

§ 8 Citations

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§ 9 Further Reading

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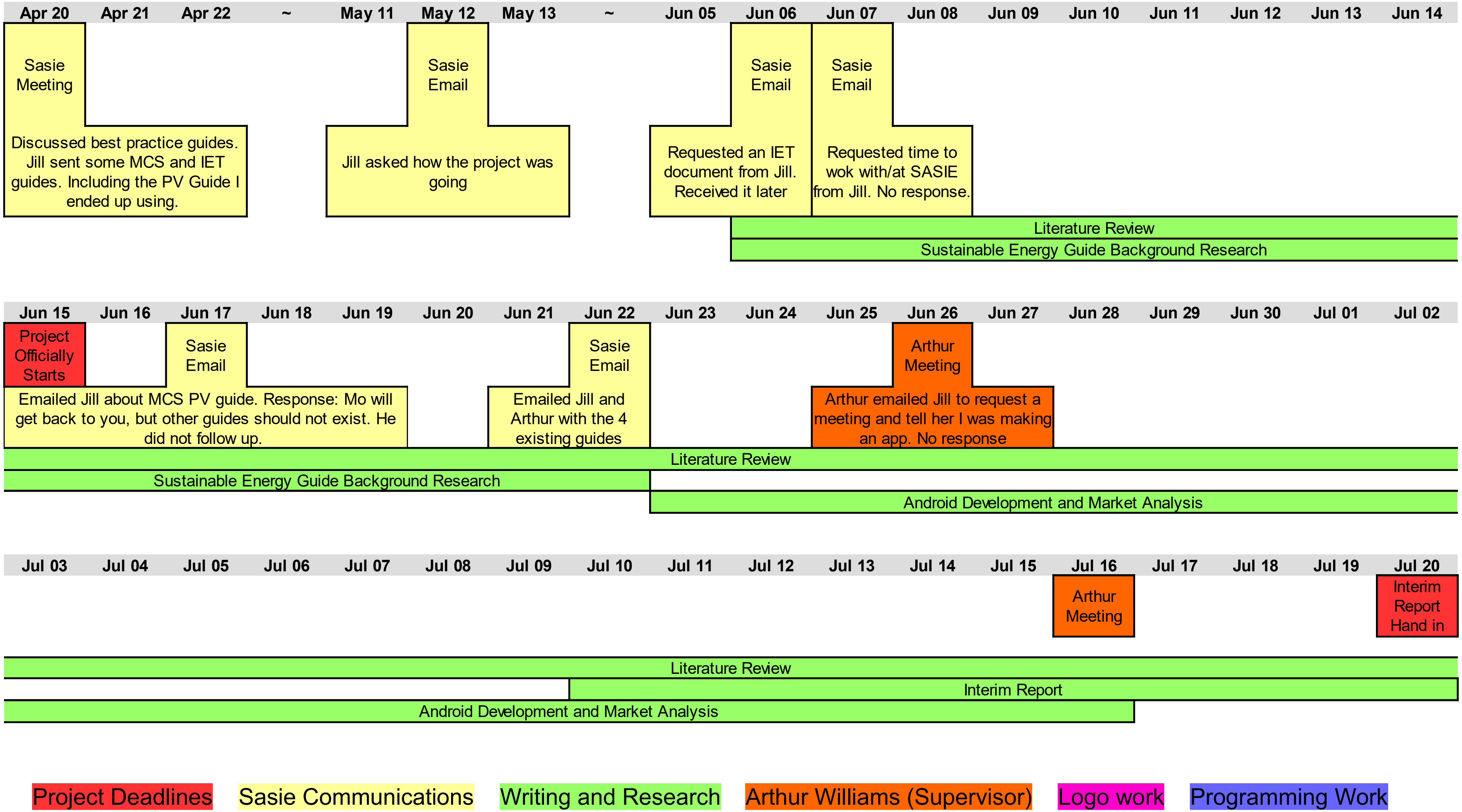
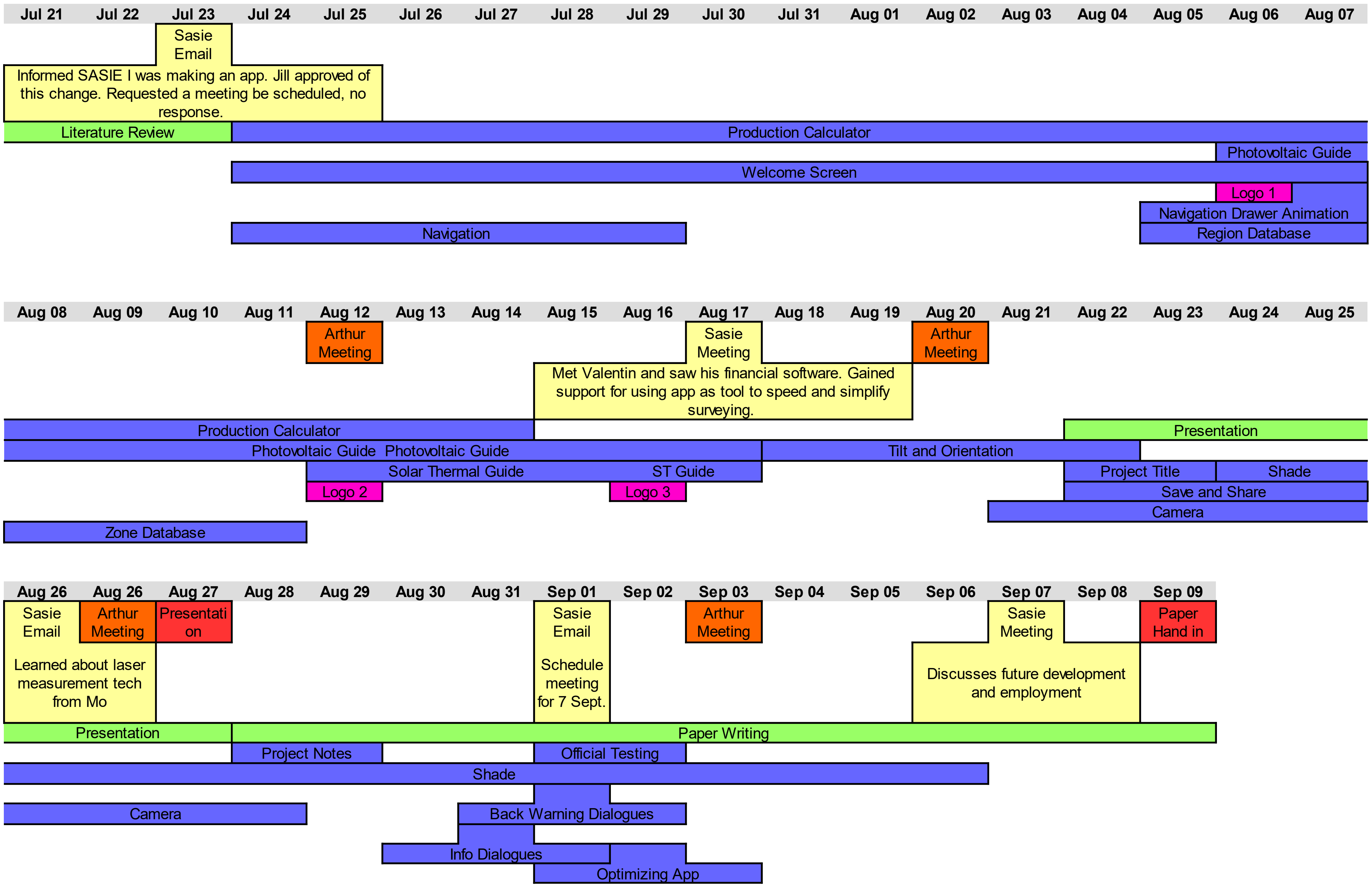
§ 10 Appendix A: Project Timeline




Jul 21
Jul 22
Jul 23
Jul 24
Jul 25
Jul 26
Jul 27
Jul 28
Jul 29
Jul 30
Jul 31
Aug 01
Aug 02
Aug 03
Aug 04
Aug 05
Aug 06
Aug 07
Sasie Email
Informed SASIE I was making an app. Jill approved of this change. Requested a meeting be scheduled, no response.
Literature Review
Production Calculator
Photovoltaic Guide
Welcome Screen
Logo 1
Navigation Drawer Animation
Navigation
Region Database
Aug 08
Aug 09
Aug 10
Aug 11
Aug 12
Aug 13
Aug 14
Aug 15
Aug 16
Aug 17
Aug 18
Aug 19
Aug 20
Aug 21
Aug 22
Aug 23
Aug 24
Aug 25
Arthur Meeting
Sasie Meeting
Arthur Meeting
Met Valentin and saw his financial software. Gained support for using app as tool to speed and simplify surveying.
Production Calculator
Presentation
Photovoltaic Guide
Photovoltaic Guide
Tilt and Orientation
Solar Thermal Guide
ST Guide
Project Title
Shade
Logo 2
Logo 3
Save and Share
Camera
Zone Database
Aug 26
Aug 26
Aug 27
Aug 28
Aug 29
Aug 30
Aug 31
Sep 01
Sep 02
Sep 03
Sep 04
Sep 05
Sep 06
Sep 07
Sep 08
Sep 09
Sasie Email
Arthur Meeting
Presentati on
Sasie Email
Arthur Meeting
Sasie Meeting
Paper Hand in
Learned about laser measurement tech from Mo
Schedule meeting for 7 Sept.
Discusses future development and employment
Presentation
Paper Writing
Project Notes
Official Testing
Shade
Camera
Back Warning Dialogues
Info Dialogues
Optimizing App

§ 11 Appendix B: Supervisor Sheets

The University of Nottingham

DEPARTMENT OF MECHANICAL, MATERIALS AND MANUFACTURING ENGINEERING

Individual Project Supervision Form

A minimum of 6 formal meetings between students and their supervisors should take place. For each of these sessions a supervision form must be completed.

Full Name of student: MATTHEW KLIMUSZKA Student ID Number: 4223034

Project title: SUSTAINABLE TECH. BEST PRACTICE GUIDES

Supervisor: ARTHUR WILLIAMS

Date of meeting: 26 June 2015

Progress since last meeting (to be completed by the student before the meeting):

Found that this work already exists → BAD
Begun investigating idea of android APP development for guides and performance calculations

I believe that my progress has been: Unsatisfactory / Adequate / Good / Excellent (delete as appropriate)

Signed: (Student) Date: 26 June 2015

Agreed plan (a draft plan can be completed by the student before the meeting, which may be modified as a result of the discussion):

Continue JAVA / Android research / learning.
Joint meeting with Jill
Write up what is currently available.

Signed: (Supervisor) 26/6/15

Date of next meeting: Next week, with Jill Holland.

Please submit the original or copies of at least 6 forms in your Appendix of your dissertation.

The University of Nottingham

DEPARTMENT OF MECHANICAL, MATERIALS AND MANUFACTURING ENGINEERING

Individual Project Supervision Form

A minimum of 6 formal meetings between students and their supervisors should take place. For each of these sessions a supervision form must be completed.

Full Name of student: Matthew Klimuszka Student ID Number: 4223034

Project title: Sustainable Tech. Best Practice Guides

Supervisor: Arthur Williams

Date of meeting: 16 July 2015

Progress since last meeting (to be completed by the student before the meeting):

- App market analyses.
- Android Market Figures
- ~2500 words written + additional research on Android development and app design.
- New Project Plan.

I believe that my progress has been: Unsatisfactory / ~~Adequate~~ / Good / Excellent (delete as appropriate)

Signed: [signature] (Student) Date: 16 July 2015

Agreed plan (a draft plan can be completed by the student before the meeting, which may be modified as a result of the discussion):

- Write and finish lit review and interim report.
- Contact Jill again
- Begin Coding

Signed: [signature] (Supervisor) 16/7/2015

Date of next meeting: 23/7/2015

Please submit the original or copies of at least 6 forms in your Appendix of your dissertation.

The University of Nottingham

DEPARTMENT OF MECHANICAL, MATERIALS AND MANUFACTURING ENGINEERING

Individual Project Supervision Form

A minimum of 6 formal meetings between students and their supervisors should take place. For each of these sessions a supervision form must be completed.

Full Name of student: Matthew Klimuszka Student ID Number: 4223034

Project title: Sustainable Tech. Best Practice Guides

Supervisor: Arthur Williams

Date of meeting: 23 July 2015

Progress since last meeting (to be completed by the student before the meeting):

Interim report finished and submitted.
Heard back from Jill.
Lit review possibly done
References formatted.

I believe that my progress has been: Unsatisfactory / Adequate / Good / Excellent (delete as appropriate)

Signed: [signature] (Student) Date: 23 July 2015

Agreed plan (a draft plan can be completed by the student before the meeting, which may be modified as a result of the discussion):

Have App designed
Significant coding progress.

Signed: A. A Williams (Supervisor) 23/07/2015

Date of next meeting: 12/08/2015

Please submit the original or copies of at least 6 forms in your Appendix of your dissertation.

The University of Nottingham

DEPARTMENT OF MECHANICAL, MATERIALS AND MANUFACTURING ENGINEERING

Individual Project Supervision Form

A minimum of 6 formal meetings between students and their supervisors should take place. For each of these sessions a supervision form must be completed.

Full Name of student: Matthew Klimuszka Student ID Number: 4223034

Project title: Sus. E. Tech. Mobile App for Site Surveying and Best Practice Ref.

Supervisor: Arthur Williams

Date of meeting: 12 Aug 2015

Progress since last meeting (to be completed by the student before the meeting):

PV Reference complete*
Production estimate utility complete
Logo + name drafted.

I believe that my progress has been: Unsatisfactory / Adequate / Good / Excellent (delete as appropriate)

Signed: [signature] (Student) Date: 12 Aug. 2015

Agreed plan (a draft plan can be completed by the student before the meeting, which may be modified as a result of the discussion):

Solar Thermal Ref.
Ethics board info.
More writing/research

Signed: A. Williams (Supervisor) 12/08/2015

Date of next meeting: 19 August 2015

Please submit the original or copies of at least 6 forms in your Appendix of your dissertation.

The University of Nottingham

DEPARTMENT OF MECHANICAL, MATERIALS AND MANUFACTURING ENGINEERING

Individual Project Supervision Form

A minimum of 6 formal meetings between students and their supervisors should take place. For each of these sessions a supervision form must be completed.

Full Name of student: Matthew Klimuszka Student ID Number: 4223034

Project title: Sus. E.Tech. Mobile App for site surveying and Best Practice Ref.

Supervisor: Arthur Williams

Date of meeting: 20 Aug 2015

Progress since last meeting (to be completed by the student before the meeting):

Solar thermal Ref done
Tilt + compass Done
Meeting with SASIE for feedback

I believe that my progress has been: Unsatisfactory / Adequate / Good / Excellent (delete as appropriate)

Signed: [signature] (Student) Date: 20-8-15

Agreed plan (a draft plan can be completed by the student before the meeting, which may be modified as a result of the discussion):

Further progress on Shading function
Preparation for presentation
Continue write-up.

Signed: [signature] (Supervisor) 20.8.15.

Date of next meeting: 26.8.15

Please submit the original or copies of at least 6 forms in your Appendix of your dissertation.

The University of Nottingham

DEPARTMENT OF MECHANICAL, MATERIALS AND MANUFACTURING ENGINEERING

Individual Project Supervision Form

A minimum of 6 formal meetings between students and their supervisors should take place. For each of these sessions a supervision form must be completed.

Full Name of student: Matthew Klimuszka   Student ID Number: 4223034

Project title: Sus. E. Tech, Mobile App for Site Surveying and Best Practice Ref.

Supervisor: Arthur Williams

Date of meeting: 26 August 2015

Progress since last meeting (to be completed by the student before the meeting):

Saving Data
Camera utility
Set Project Name
Presentation

I believe that my progress has been: Unsatisfactory / Adequate / Good / Excellent (delete as appropriate)

Signed: [signature] (Student) Date: 26-8-15

Agreed plan (a draft plan can be completed by the student before the meeting, which may be modified as a result of the discussion):

Polish App
Work on shading
Write

Signed: [signature] (Supervisor) 26-8-15

Date of next meeting: 3/9/15

Please submit the original or copies of at least 6 forms in your Appendix of your dissertation.

The University of Nottingham

DEPARTMENT OF MECHANICAL, MATERIALS AND MANUFACTURING ENGINEERING

Individual Project Supervision Form

A minimum of 6 formal meetings between students and their supervisors should take place. For each of these sessions a supervision form must be completed.

Full Name of student: Matthew Klimuszka Student ID Number: 4223034

Project title: Sustainable Energy Tech. Mobile App for Site Survey and Best Practice Ref.

Supervisor: Arthur Williams

Date of meeting: 3 September 2015

Progress since last meeting (to be completed by the student before the meeting):

5000 Words written
Appendix created
Code Tested and fixed
added info dialogues
added various features
Presentation finished and given

I believe that my progress has been: Unsatisfactory / Adequate / Good / Excellent (delete as appropriate)

Signed: [signature] (Student) Date: 3 Sept 2015

Agreed plan (a draft plan can be completed by the student before the meeting, which may be modified as a result of the discussion):

Finish!

Signed: [signature] (Supervisor) 3/09/2015

Date of next meeting: —

Please submit the original or copies of at least 6 forms in your Appendix of your dissertation.

§ 12 Appendix C: Hardware

The HTC One Mini is rooted and running CyanogenMod version 11-20141112-SNAPSHOT-M12-m4, which has an Android version of 4.4.4.

The HiSense Sero 7 Pro is rooted and running Android version 5.1 using a DoPa ASOP ROM build number dopa_m470-userdebug 5.1 LMY47I eng.dolorespark.20150408.131248 test-keys.

These devices provide both a smartphone and a tablet system for testing, and the two most recent major Andoid releases, Lollipop and KitKat. However, since they are both running custom ROMs, things may behave differently than if they were running stock software. This will extend the testing environment past what the emulator provides, but it also means that there is no unrooted physical device available to test on. Most devices are unrooted, so the emulator will have to cover that large portion of installation scenarios.

§ 13 Appendix D: Tilt and Orientation

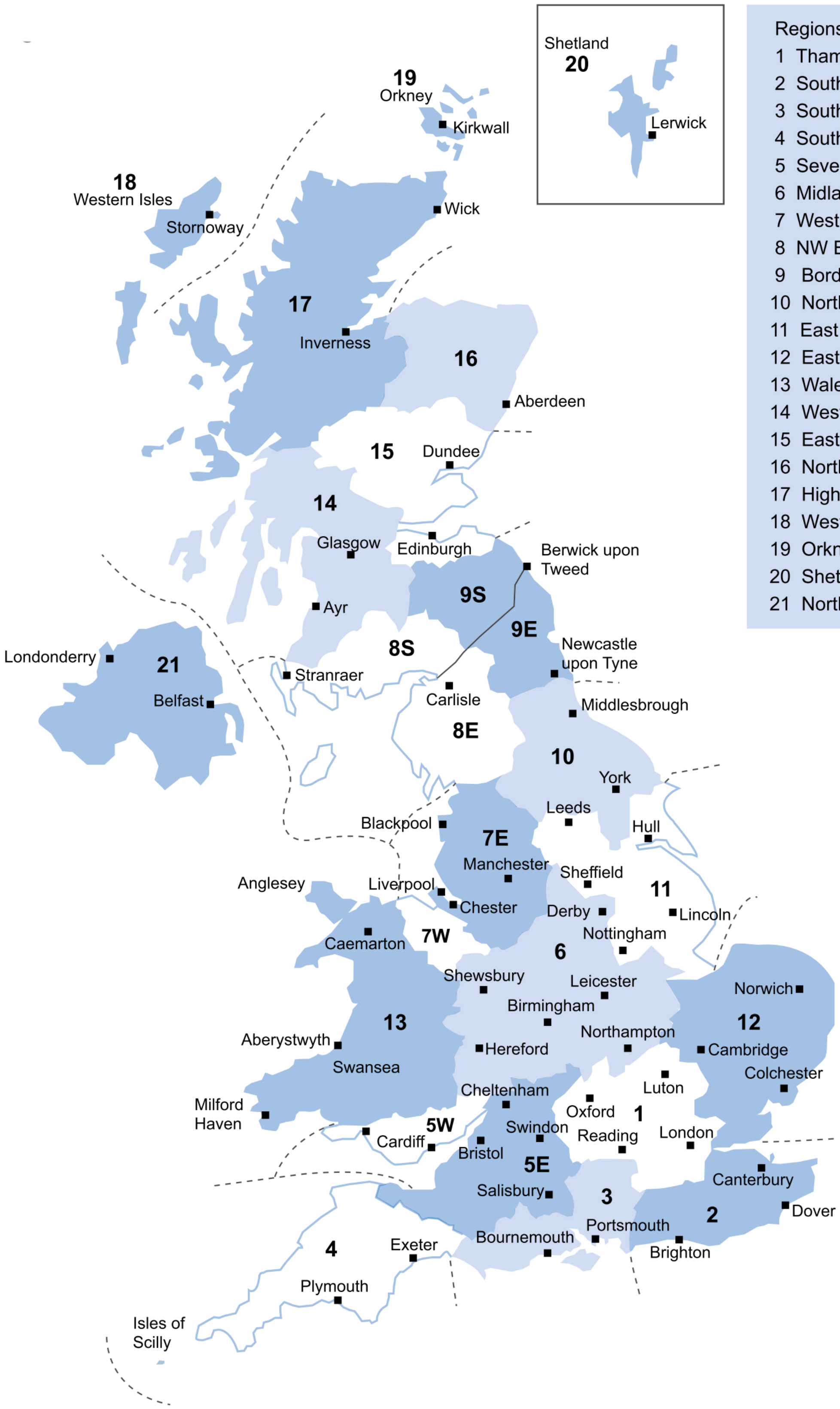
```
@Override
public void onSensorChanged(SensorEvent event) {
    if (event.sensor == mAccelerometer) {
        System.arraycopy(event.values, 0, mLastAccelerometer, 0, event.values.length);
        mLastAccelerometerSet = true;
        if (pitchchange) { //update pitch if measurement is not locked
            float[] g ;
            g = event.values.clone();

            float norm_Of_g = (float) Math.sqrt(g[0] * g[0] + g[1] * g[1] + g[2] * g[2]);
            // Normalize the accelerometer vector
            g[0] = g[0] / norm_Of_g;
            g[1] = g[1] / norm_Of_g;
            g[2] = g[2] / norm_Of_g;

            //
            inclination = (int) Math.round(Math.toDegrees(Math.asin(g[1])));
            inclinationview.setText(inclination + "°");
        }
    } else if (event.sensor == mMagnetometer) {
        System.arraycopy(event.values, 0, mLastMagnetometer, 0, event.values.length);
        mLastMagnetometerSet = true;
    }
    if (mLastAccelerometerSet && mLastMagnetometerSet) { //do stuff with compass
      if (orientationchange) { //Update compass if measurement is not locked
          // Put rotation matrix into variable mR using the most recent accelerometer and
magnetometer readings
          SensorManager.getRotationMatrix(mR, null, mLastAccelerometer, mLastMagnetometer);
```

```
            //Use rotation matrix to get the orientation
            SensorManager.getOrientation(mR, mOrientation);
            //by definition, the first value of the orientation array is the azimuth in radians
            float azimuthInRadians = mOrientation[0];
              // normally, azimuth includes directionality of azimuth, but we don't care about that
              //So add 360 and then divide with remainder to get positive azimuth
            float azimuthInDegress = (float) (Math.toDegrees(azimuthInRadians) +360) % 360;
              //A precision of 5 degrees is required for MCS methodology
            float azimuthInDegressRounded = Math.round(azimuthInDegress / 5) * 5;
            //Convert azimuth (degrees from North) to degrees from south
            if (azimuthInDegressRounded <= 180) {
                orientation = azimuthInDegressRounded;
            } else {
                orientation = 360 - azimuthInDegressRounded;
            }
            degreebox.setText(String.format("%.0f", orientation) + "°");
            RotateAnimation ra = new RotateAnimation(
                    mCurrentDegree,
                    -azimuthInDegress,
                    Animation.RELATIVE_TO_SELF, 0.5f,
                    Animation.RELATIVE_TO_SELF,
                    0.5f);
            ra.setDuration(250);
            ra.setFillAfter(true);
            mPointer.startAnimation(ra);
            mCurrentDegree = -azimuthInDegress;
        }
    }
}
```

§ 14 Appendix E: Solar Potential Regions



Regions
1 Thames
2 South East England
3 Southern England
4 South West England
5 Severn
6 Midlands
7 West Pennines
8 NW England/ SW Scotland
9 Borders
10 North East England
11 East Pennines
12 East Anglia
13 Wales
14 West Scotland
15 East Scotland
16 North East Scotland
17 Highland
18 Western Isles
19 Orkney
20 Shetland
21 Northern Ireland

Postcode	Zone	Postcode	Zone	Postcode	Zone	Postcode	Zone
AB	16	G	14	N	1	SK	7E
AL	1	GL	5E	NE	9E	SK13	6
B	6	GU	1	NG	11	SK17	6
BA	5E	GU11-12	3	NN	6	SK22-23	6
BB	7E	GU14	3	NP	5W	SL	1
BD	11	GU28-29	2	NPS	13	SM	1
BD23-24	10	GU30-35	3	NR	12	SN	5E
BH	3	GU46	3	NW	1	SN7	1
BL	7E	GU51-52	3	OL	7E	SO	3
BN	2	HA	1	OX	1	SP	5E
BR	2	HD	11	PA	14	SP6-11	3
BS	5E	HG	10	PE	12	SR	9E
BT	21	HP	1	PE9-12	11	SR7-8	10
CA	8E	HR	6	PE20-25	11	SS	12
CB	12	HS	18	PH	15	ST	6
CF	5W	HU	11	PH19-25	17	SW	1
CH	7E	HX	11	PH26	16	SY	6
CH5-8	7W	IG	12	PH30-44	17	SY14	7E
CM	12	IP	12	PH49	14	SY15-25	13
CM21-23	1	IV	17	PH50	14	TA	5E
CO	12	IV30-32	16	PL	4	TD	9S
CR	1	IV36	16	PO	3	TD12	9E
CT	2	KA	14	PO18-22	2	TD15	9E
CV	6	KT	1	PR	7E	TF	6
CW	7E	KW	17	RG	1	TN	2
DA	2	KW15-17	19	RG21-29	3	TQ	4
DD	15	KY	15	RH	1	TR	4
DE	6	L	7E	RH10-20	2	TS	10
DG	8S	LA	7E	RH77	2	TW	1
DH	10	LA7-23	8E	RM	12	UB	1
DH4-5	9E	LD	13	S	11	W	1
DL	10	LE	6	S18	6	WA	7E
DN	11	LL	7W	S32-33	6	WC	1
DT	3	LL23-27	13	S40-45	6	WD	1
DY	6	LL30-78	13	S49	6	WF	11
E	1	LN	11	SA	5W	WN	7E
EC	1	LS	11	SA14-20	13	WR	6
EH	15	LS24	10	SA31-48	13	WS	6
EH43-46	9S	LU	1	SA61-73	13	WV	6
EN	1	M	7E	SE	1	YO	10
EN9	12	ME	2	SG	1	YO15-16	11
EX	4	MK	1			YO25	11
FK	14	ML	14			ZE	20
FY	7E						

§ 15 Appendix F: Production Calculator

```
  calcbutton.setOnClickListener(new View.OnClickListener() {
      public void onClick(View view) {
          //Assign field values to variables.
          final Spinner pitchspinner = (Spinner) getView().findViewById(R.id.pitchspinner);
          final Spinner orientationspinner = (Spinner)
getView().findViewById(R.id.orientationspinner);
          final Spinner shadespinner = (Spinner) getView().findViewById(R.id.shadespinner);
          final Spinner postcodespinner = (Spinner) getView().findViewById(R.id.postcodespinner);
           pitch = pitchspinner.getSelectedItemPosition();
          Integer orientaationsel = orientationspinner.getSelectedItemPosition();
          Integer shadesel = shadespinner.getSelectedItemPosition();
          Integer postcodesel = postcodespinner.getSelectedItemPosition();
          //assign actual values
           orientation = orientaationsel * 5;
           shadefactor = shadesel / 100.0;
           postregion = "1";
          RegionDatabase mDb = new RegionDatabase(getActivity());
          SQLiteDatabase db = mDb.getReadableDatabase();
          String[] columns = {"Region"};
          String Selection = "_id=?";
          String[] SelectionArgs = {"" + postcodesel};
          Cursor cursor = db.query("Region_Key", columns, Selection, SelectionArgs, null, null, null,
null);
          cursor.moveToNext();
          postregion = cursor.getString(cursor.getColumnIndexOrThrow("Region"));
          String[] columnsx = {String.format("\"%s\"", orientation), "Slope"};
          Selection = "Slope=?";
          String[] SelectionArgsx = {"" + pitch};
          String ratio = "1";
```

```
          cursor = db.query(String.format("\"%s\"", postregion), columnsx, Selection, SelectionArgsx,
null, null, null, null);
          cursor.moveToNext();
          ratio = cursor.getString(cursor.getColumnIndexOrThrow("" + orientation));
          // now ratio contains a string,  pitch and orientation contain the required integers, and
shadefactor contains a double.
          EditText temp = (EditText) getView().findViewById(R.id.kwpedittext);
           Wp = Integer.parseInt((temp.getText().toString().replaceAll("[\\D]", "")));
          kK = Integer.parseInt(ratio);
           Production = kK * shadefactor * Wp / 1000; //Gives answer in kWh
          TextView productionview = (TextView) getView().findViewById(R.id.viewproduction);
          productionview.setText(String.format("%.2f", Production));
          //Find optimum values based on location, pitch, and/or orientation.
          // optimum orientation will always be 0 degrees. So this will represent the overall optimum
for the location
          String[] optimumcolumn = {"Slope", String.format("\"%s\"", 0)};
          //return all ratios and their slopes for south orientation in descending order
          cursor = db.query(String.format("\"%s\"", postregion), optimumcolumn, null, null, null,
null, String.format("\"%s\"", 0) + " DESC", null);
          cursor.moveToNext();
          String optimumratio_overall = cursor.getString(cursor.getColumnIndexOrThrow("" + 0)); //get
highest ratio
          //Return entries with this highest ratio
          Selection = String.format("\"%s\"", 0) + "=?";
          String[] SelectionArgsz = {"" + optimumratio_overall};
          cursor = db.query(String.format("\"%s\"", postregion), optimumcolumn, Selection,
SelectionArgsz, null, null, null, null);
          //Store these pitches in an array
          List<String> pitcharray_overall = new ArrayList<String>();
          while (cursor.moveToNext()) {
              String temp2 = cursor.getString(cursor.getColumnIndexOrThrow("Slope"));
              pitcharray_overall.add(temp2);
          }
```

```
            if (pitcharray_overall.size() == 1) {
                pitch_overall = "" + pitcharray_overall.get(0);
            } else {
                pitch_overall = "" + pitcharray_overall.get(0) + "-" +
pitcharray_overall.get(pitcharray_overall.size() - 1);
            }
            Integer optimum_kK_overall = Integer.parseInt(optimumratio_overall);
             optimum_Production_overall = optimum_kK_overall * shadefactor * Wp / 1000; //Gives answer
in kWh
            // Find optimum pitch and ratio based on current orientation and location
            //return all ratios and their slopes for set orientation in descending order
            cursor = db.query(String.format("\"%s\"", postregion), columnsx, null, null, null, null,
String.format("\"%s\"", orientation) + " DESC", null);
            cursor.moveToNext();
            String optimumratio_orient = cursor.getString(cursor.getColumnIndexOrThrow("" +
orientation)); //get highest ratio
            //Return entries with this highest ratio
            Selection = String.format("\"%s\"", orientation) + "=?";
            String[] SelectionArgsa = {"" + optimumratio_orient};
            cursor = db.query(String.format("\"%s\"", postregion), columnsx, Selection, SelectionArgsa,
null, null, null, null);
            //Store these pitches in an array
            List<String> pitcharray_orient = new ArrayList<String>();
            while (cursor.moveToNext()) {
                String temp3 = cursor.getString(cursor.getColumnIndexOrThrow("Slope"));
                pitcharray_orient.add(temp3);
            }
            if (pitcharray_orient.size() == 1) {
                pitch_orient = "" + pitcharray_orient.get(0);
            } else {
                pitch_orient = "" + pitcharray_orient.get(0) + "-" +
pitcharray_overall.get(pitcharray_overall.size() - 1);
            }
```

```
            Integer optimum_kK_orient = Integer.parseInt(optimumratio_orient);
            optimum_Production_orient = optimum_kK_orient * shadefactor * Wp / 1000; //Gives answer in
kWh
            //Show optimum info.
            String optimum_info = "Using the optimum slope (" + pitch_orient + "\u00B0), this would be
" + String.format("%.2f", optimum_Production_orient) + " kWh.";
            String optimum_info_overall;
            if (orientation == 0) {
                optimum_info_overall = "";
            } else {
                optimum_info_overall = " The maximum possible production is " + String.format("%.2f",
optimum_Production_overall) + " kWh, where slope is " + pitch_overall + "\u00B0 and orientation is
0\u00B0";
            }
            TextView optimumview = (TextView) getView().findViewById(R.id.textoptimuminfo);
            optimumview.setText(optimum_info + optimum_info_overall);
            optimumview.setBackgroundColor(Color.parseColor("#00FFFFFF"));
            optimumview.setTextSize(15);
            db.close();
            cursor.close();
            mDb.close();
            mCallback.onSaveDataClicked(pitch_orient, optimum_Production_orient, pitch_overall,
optimum_Production_overall, pitch, orientation, Production, shadefactor, postregion, kK, Wp);
            // optimum slope, optimum production with that slope, optimum slope for south facing panel,
highest possible production, slope chosen, orientation chosen, production calculated, shading factor,
location, ratio, Wp
        }
    });
```

§ 16 Appendix G: Photovoltaic Reference

The contents of the PV Reference utility is here. It is based largely on the MCS document *Guide to the Installation of Photovoltaic Systems* [1]

§ 16.1 About

The information in this guide is based on the MCS document “Guide to the Installation of Photovoltaic Systems” published in 2012 with support and assistance from the MCS Solar PV Technical Working Group. This information is for general guidance only and does not replace professional training. The practices outlined in this guide are based on the climate of the UK.

§ 16.2 Glossary

a.c. Side

Part of a PV installation from the a.c. terminals of the PV inverter to the point of connection of the PV supply cable to the electrical installation

d.c. Side

Part of a PV installation from a PV cell to the d.c. terminals of the PV inverter

Distribution Network Operator (DNO)

The organisation that owns or operates a Distribution Network and is responsible for confirming requirements for the connection of generating units to that Network

Earthing

Connection of the exposed-conductive-parts of an installation to the main earthing terminal of that installation

Electricity Network

An electrical system supplied by one or more sources of voltage and comprising all the conductors and other electrical and associated equipment used to conduct electricity for the purposes of conveying energy to one or more Customer’s installations, street electrical fixtures, or other Networks

Equipotential Zone

Where exposed-conductive parts and extraneous-conductive parts are maintained at substantially the same voltage

Exposed-Conductive-Part

Conductive part of equipment which can be touched and which is not normally live, but which can become live when basic insulation fails

Extraneous-Conductive-Part

A conductive part liable to introduce a potential, generally Earth potential, and not forming part of the electrical system

Isc (stc) Short-Circuit Current

Short-circuit current of a PV module, PV string, PV array or PV generator under standard test conditions

Islanding

Any situation where a section of electricity Network, containing generation, becomes physically disconnected from the DNOs distribution Network or User's distribution Network; and one or more generators maintains a supply of electrical energy to that isolated Network

Isolating Transformer

Transformer where the input & output windings are electrically separated by double or reinforced insulation

Isolation

A function intended to cut off for reasons of safety the supply from all, or a discrete section, of the installation by separating the installation or section from every source of electrical energy

Isolator

A mechanical switching device which, in the open position, complies with the requirements specified for the isolating function. An isolator is otherwise known as a disconnector

Lightning Protection

A means of applying protective measures to afford protection to persons, property and livestock against the effects of a lightning strike

PME – Protective Multiple Earthing

An earthing arrangement, found in TN-C-S systems, in which the supply neutral conductor is used to connect the earthing conductor of an installation with Earth, in accordance with the Electrical Safety, Quality and Continuity Regulations 2002

Protective Equipotential Bonding - (also referred to as Equipotential Bonding)

Electrical connection maintaining various exposed-conductive-parts and extraneous-conductive-parts at substantially the same potential

PV a.c. Module

Integrated module/convertor assembly where the electrical interface terminals are a.c. only. No access is provided to the d.c. side

PV Array

Mechanically and electrically integrated assembly of PV modules, and other necessary components, to form a d.c. power supply unit

PV Array Cable

Output cable of a PV array

PV Array Junction Box

Enclosure where all PV strings of any PV array are electrically connected and where protection devices can be located

PV String

A number of PV modules are connected in series to generate the required output voltage

PV Cell

Basic PV device which can generate electricity when exposed to light such as solar radiation

PV Charge Controller

A device that provides the interface between the PV array and a battery

PV d.c. Main Cable

Cable connecting the PV array junction box to the d.c. terminals of the PV convertor

PV Grid-Connected System

A PV generator operating in ‘parallel’ with the existing electricity network

PV Installation

Erected equipment of a PV power supply system

PV Inverter (also known a PV Convertor)

Device which converts d.c. voltage and d.c. current into a.c. voltage and a.c. current

PV Kilowatts Peak (kWp)

Unit for defining the rating of a PV module where kWp = watts generated at stc

PV Module Maximum Series Fuse

A value provided by the module manufacturer on the module nameplate & datasheet (a requirement of IEC61730-2)

PV Module

Smallest completely environmentally protected assembly of interconnected PV cells

PV MPP Tracker (MPPT)

A component of the d.c. input side of an inverter designed to maximise the input from the array by tracking voltage and current

PV Self-Cleaning

The cleaning effect from rain, hail etc. on PV arrays which are sufficiently steeply inclined

PV String Cable

Cable connecting PV modules to form a PV string

PV String Fuse

A fuse for an individual PV string

PV Supply Cable

Cable connecting the AC terminals of the PV convertor to a distribution circuit of the electrical installation

PV Standard Test Conditions (stc)

Test conditions specified for PV cells and modules (25°C, light intensity 1000W/m 2 , air mass 1.5)

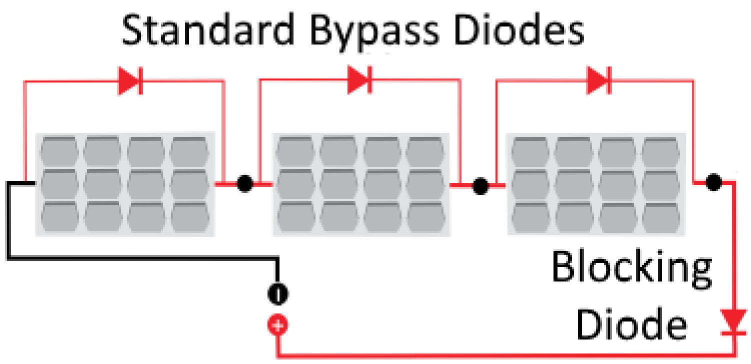
Voc

Open circuit d.c. Voltage

§ 16.3 Blocking Diodes

§ 16.3.1 Purpose

Blocking diodes are not commonly used in a grid-connect system as their function is better served by the installation of a string fuse. However, for multi-string arrays with some types of PV module, particularly thin-film types, it may not be possible to provide adequate overcurrent / reverse current protection with string fuses or MCBs alone. If blocking diodes are used, they should still be supplemented by string fuses.



§ 16.3.2 Blocking Diode Specifications

- Reverse voltage rating > V_{oc} × M × 2.3
- Current rating > 1.4 × I_{sc}
- Have adequate cooling (heatsinks) if required where I_{sc} is the relevant short circuit current for the string / sub array / array.

§ 16.3.3 Note

- The installation of a blocking diode results in a small voltage drop across the diode
- Blocking diodes may fail as a short-circuit and therefore require regular testing.
- Blocking diodes should not be confused with bypass diodes, which are intended to allow current to bypass cells that have a high resistance (usually caused by shading).

§ 16.4 Cables AC

The PV system inverter(s) should be installed on a dedicated final circuit to the requirements of BS 7671 in which:

- No current-using equipment is connected
- No provision is made for the connection of current-using equipment
- No socket-outlets are permitted.

Note: For the purposes of this guide a datalogger is not considered current-using equipment and can be connected into the same final circuit as the PV system.

An inverter must not be connected by means of a plug with contacts which may be live when exposed. A.c. cables are to be specified and installed in accordance with BS 7671. The a.c. cable connecting the inverter(s) to the consumer unit should be sized to minimise voltage drop. A 1% drop or less is recommended.

Protection for the cable from the inverter(s) must be provided at the **distribution board**. This protective measure shall be specified and installed in accordance with the requirements of BS 7671. In very many cases the current limiting nature of the PV array and inverter(s) omits the requirements for overload protection and therefore the designer only need to consider fault current protection. The protection afforded at the origin of the circuit (the distribution board) in accordance with BS 7671, means there is no requirement for additional overcurrent protection to be installed at the inverter end of the a.c. installation.

\n\tCables are to be well supported, especially those cables **exposed to the wind**. Cables must be routed in prescribed zones or within mechanical protection, fully supported / cable tied (using UV stabilised ties) and they must also be protected from sharp edges.

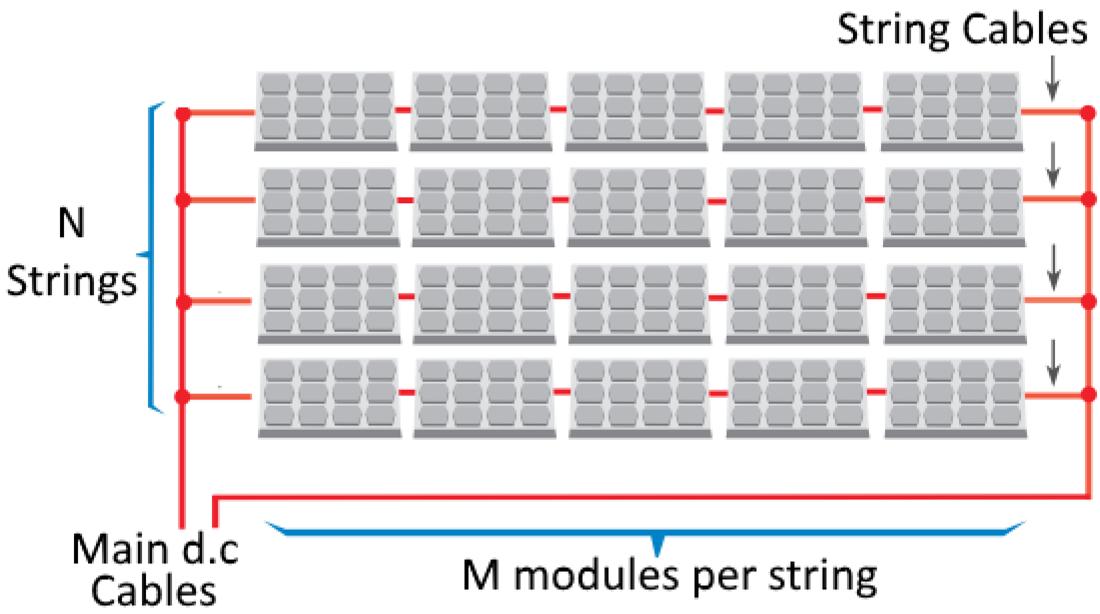
§ 16.5 Cables DC

§ 16.5.1 String Cable Minimum Rating

Voltage: $V_{oc}(stc) \times 1.15 \times M$

Current: $I_{sc}(stc) \times 1.25 \times (N-1)$

where M is the number of modules per string and N is the number of strings.

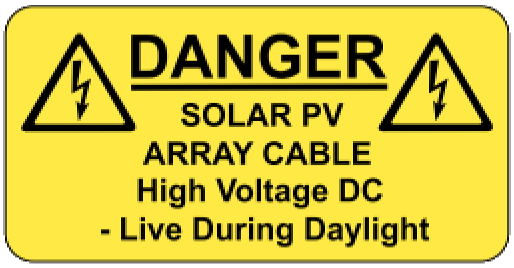


The cable current carrying capacity must be calculated according to the requirements of BS 7671. This shall include factors taking into account installation conditions such as cable installation method, solar gains and grouping etc. The cable current carrying capacity after de-rating factors have been applied must exceed the string fuse rating and must exceed the $I_{sc} \times 1.25$.

Cable Runs

The overall **voltage drop,** at array maximum operating power (stc), between the array and the inverter is under 3%. Cables should be sized in accordance with BS 7671. See *DC Current and Voltage* for voltage and current calculations. It is expected that “PV cables” are used if they are available. It is recommended that all cables comply with UL 4703, or TUV 2 Pfg 1169 08.2007.

To minimise the risk of faults, cable runs should be as short as practicable. Runs over 20m require labels (below) to be fixed every 5-10m. Cabled over about 50m should be installed in earthed metal conduit or trunking, or be screened cables such as armoured. Positive and negative cables of the same string or main d.c. supply should be installed together, avoiding the creation of loops in the system. This requirement includes any associated earth/bonding conductors. Exterior cable **colour coding** is not required for PV systems.



Cables routed behind a PV array must be rated for a temperature range of at least of **15°C to 80°C.** External cables and ties should be UV stable and water resistant. Where cables are likely to be subjected external movement, i.e. those mounted immediately behind the array, it is recommended that they be **flexible** (multi-stranded) to allow for thermal/wind movement of arrays/modules.

PV array cables almost exclusively rely on **double or reinforced insulation** as their means of shock protection they should not be buried in walls or otherwise hidden in the building structure as mechanical damage would be very difficult to detect and may lead to increase instances of shock and fire risk.

§ 16.5.2 Plug and Socket Connectors

Plugs and socket connectors mated together in a PV system shall be of the same type from the same manufacturer and shall comply with BS EN 50521. Different brands may only be interconnected where a test report has been provided that complies with BS EN 50521.

Connectors readily accessible to ordinary persons shall be of the locking type, requiring a tool or two separate actions to separate and shall have sign attached that reads: ‘Do not disconnect d.c. plugs and sockets under load’

§ 16.6 Current and Voltage Ratings DC

§ 16.6.1 Crystalline Cell Minimum Rating

Voltage: V_{oc}(stc) × 1.15

Current: I_{sc}(stc) ×1.25

Using max lifetime values for temperature range of -15°C to 80°C and irradiance up to 1,250 W/m^2 . Cables should be sized in accordance with BS 7671 and the overall voltage drop, at max operating power, between the array and the inverter is under 3%.

Note:Some types of PV modules have temperature coefficients that push power output outside standard calculations. In addition, some thin film modules have an electrical output that is much higher during their first few weeks. To avoid oversizing the inverter, the array could be left disconnected for that initial period, refer to the manufacturer.

Array Voltage Exceeds 120V

Double insulation or reinforced insulation, appropriate barriers, and separation of parts must be applied to all parts of the d.c. circuit to facilitate a level of protection equivalent to the protective measure “double or reinforced insulation” as defined in BS 7671- Section 412.

Array Voltage Exceeds 1000V

Due to the added complexities and dangers associated with systems of a higher voltage than normal, the PV array should not be installed on a building. In addition, access should be restricted to only competent, skilled or instructed persons.

§ 16.7 Earthing AC

Earthing of the inverter at the a.c. terminations will still be necessary where the inverter is a Class I piece of equipment and must be applied where necessary. Where class I inverters are used externally (e.g. field mount systems) careful consideration must be given to the requirements for earthing.

§ 16.8 Earthing DC

As the d.c. side of PV systems is a current limiting generating set, the protective measure ADS is almost never used and is outside of the scope of this guidance. In these circumstances, where the d.c. side of the installation is constructed to meet the requirements of an installation using double or reinforced insulation, no connection to earth between the PV Modules or frame and main earthing terminal would be required.

A connection to earth of any of the current carrying d.c. conductors is not recommended. However, earthing of one of the live conductors of the d.c. side is permitted, if there is at least simple separation between the a.c. and the d.c. side. Where a functional earth is required, it is preferable that where possible this be done through **high impedance** (rather than directly).

The designer must confirm whether the **inverter** is suitable for earthing of a d.c. conductor. Transformerless inverters will not be suitable, and an earthed conductor may interfere with the inverter’s built-in d.c. insulation monitoring.

Where there is a hardwired connection to earth, there is the potential for significant fault currents to flow if an earth fault occurs somewhere in the system. A **ground fault (earth fault) interrupter** and alarm system can interrupt the fault current and signal that there has been a problem. The interrupter (such as a fuse) is installed in series with the ground connection and selected according to array size. It is important that the alarm is sufficient to initiate action, as any such earth fault needs to be immediately investigated and action taken to correct the cause.

§ 16.8.1 Required Interrupter Rating

Array size	Overcurrent rating
≤ 3kWp	≤ 1A
3-100KWp	≤ 3A
> 100kWp	≤ 5A

§ 16.9 Inverters

§ 16.9.1 Requirements

Inverters must carry a Type Test certificate to the requirements of Engineering

Recommendation G83 or G59 as applicable unless specifically agreed by an engineer employed by or appointed by the DNO for this purpose, and in writing.

A key safety consideration is that the PV system will disconnect when the distribution system is not energised.

Where a system features **multiple strings/arrays** with significantly different orientation or inclination, the strings or arrays should be connected to an inverter with a multiple MPPT function or separate inverters should be utilised.

§ 16.9.2 Sizing Factors

- The inverters available for use in the UK (not all manufacturers have G83 / G59)
- Array voltage fluctuations due to operating temperature
- The maximum permissible d.c. input voltage of the inverter
- The MPP (maximum power point) voltage range of the inverter
- The desired inverter – array power ratio
- Inverter matching is to be done using the guidance from the inverter manufacturer – typically using the manufacturer’s system sizing software.

§ 16.9.3 Inverter Rating Minimum

Voltage: V_{oc}(stc) × 1.15

Current: I_{sc}(stc) ×1.25

This must include any initial overvoltage period which is a feature of some module types. This is to include verifying that the inverter can safely withstand the array open circuit voltage maximum at -15°C.

§ 16.9.4 Temperature range

While an inverter must be able to safely withstand array operation between -15°C to 80°C, it is permissible for a narrower temperature band (e.g. -10°C to 70°C) to be used when looking at the operational mpp range of the inverter. In such cases, an assessment should be made as to the temperature range acceptable and appropriate for that particular site and array mounting method (e.g. some building integrated systems will operate at higher temperatures than “on-top” systems)

§ 16.9.5 Power ratio

It is common practice for an inverter power to be less than the PV array rating. In the UK, inverters are typically sized in the range of 100 - 80% of array capacity. However, in certain circumstances and depending on the inverter used, ratios outside this are sometimes utilised (NB: Inverter power is taken to be maximum steady state a.c. power output).

§ 16.9.6 Inverter ventilation

Inverters generate heat and should be provided with sufficient ventilation. Clearance distances as specified by the manufacturer (e.g to a heatsink) should also be observed. Inverter locations such as Plant or Boiler rooms, or roof spaces prone to high temperatures, should be carefully considered to avoid overheating. Failure to follow this can cause a loss in system performance as the inverter will de-rate when it reaches its maximum operating temperature. This should be highlighted within the operation and use manual, left with the customer and ideally with a label – “not to block ventilation” – placed next to the inverter.

§ 16.9.7 Protection

Protection for the cable from the inverter(s) must be provided at the distribution board. This protective measure shall be specified and installed in accordance with the requirements of BS 7671. In very many cases the current limiting nature of the PV array and inverter(s) omits the requirements for **overload protection** and therefore the designer only need to consider **fault current protection**. The protection afforded at the origin of the circuit (the distribution board) in accordance with BS 7671, means there is no requirement for additional overcurrent protection to be installed at the inverter end of the a.c. Installation.

It is recommended that Inverters carry a sign ‘Inverter - isolate a.c. and d.c. before carrying out work’.

§ 16.10 Isolation and Switching (AC)

The PV system shall be connected to an isolation switch that fulfils the following conditions:

- Isolates line and neutral conductors
- Be securable in the OFF position
- Located in an accessible location

Isolation and switching of the a.c. side of the installation shall also comply with the requirements of BS 7671. This is to include the provision of an isolator adjacent to the inverter to disconnect the inverter from the source of supply (AC). In its simplest form, for a single phase inverter, an unswitched fused connection unit mounted adjacent to the inverter may be used to fulfil this requirement. It is however suggested that for the purposes of routine maintenance a **switched fused connection unit** offers a better degree of control and therefore should be used as a minimum.

Note: At the point of installation of any a.c. switch-disconnector, the public supply should be considered the source and the PV installation the load.

§ 16.11 Isolation and Switching (DC)

§ 16.11.1 Switch Disconnector Specifications (d.c.)

- The switch must isolate all live conductors (typically double pole to isolate PV array positive and negative conductors)
- The switch must be rated for d.c. operation at the system voltage maximum as calculated
- The switch must be rated for d.c. operation at the system current maximum as calculated
- The switch must be labelled as ‘PV array d.c. isolator’, with the ON and OFF positions clearly marked.
- Switch enclosures should also be labelled with ‘Danger - contains live parts during daylight’.
- A circuit breaker may also be used provided it meets all the above requirements

§ 16.11.2 Switch Disconnector Types

- A physically separate switch-disconnecter mounted adjacent to the inverter
- A switch-disconnecter that is mechanically connected to the inverter – that allows the inverter to be removed from the section containing the switch-disconnecter without risk of electrical hazards
- A switch-disconnecter integral to the inverter, if the inverter includes a means of isolation only operable when the switch-disconnecter is in the open position (e.g. plugs only accessible once the switch disconnector handle is removed)
- A switch-disconnecter integral to the inverter, if the inverter includes a means of isolation (e.g. plugs) which can only be operated with a tool and is labelled with a readily visible warning sign or text indicating ("Do not disconnect under load")

§ 16.11.3 Exception

A d.c. isolator may not always be necessary where the system fulfils all of the following:

- Connects only one module per inverter
- Does not require the extension of the PV module d.c. cables beyond the length of the original factory fitted cables
- Does not exceed the voltages within the band of ELV (Not exceeding 50 V a.c. or 120 V ripple-free d.c. whether between conductors or to Earth.)

• Has a plug and socket type connector arrangement for the d.c. Cables. If it is decided to omit the switch disconnecter this shall be recorded as a departure on the Electrical installation certificate.

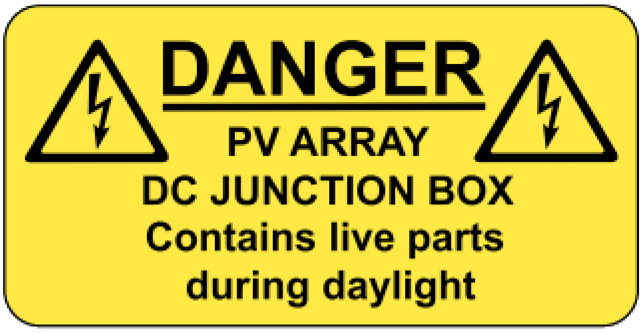
§ 16.12 Junctioning (DC)

In general cable junctions shall either be by an approved plug and socket connector or contained within a d.c. Junction Box. However in certain limited circumstances it may be necessary for an in-line cable junction to be made (e.g. soldered extension to a module flying lead) although this should be avoided if at all possible.

Where multiple PV sub-arrays and or string conductors enter a junction box they should be grouped or identified in pairs so that positive and negative conductors of the same circuit may easily be clearly distinguished from other pairs.

Plug and socket **"Y" connectors** can also be used to replace a junction box. It is good practice to keep "Y" connectors in accessible locations and where possible note their location on layout drawings, to ease troubleshooting in future.

The d.c. junction box must be labelled with the following.



§ 16.13 Lightning Protection

In most situations, PV panels do not significantly increase lightning risks. However, where buildings or structures are considered to be at greater risk, for example very tall, or in an exposed location, the designer of the a.c. electrical system may have chosen to design or apply protective measures such as installation of conductive air rods or tapes. If the building or dwelling is fitted with a lightning protection system (LPS), a suitably qualified person should be consulted as to whether, in this particular case, the array frame should be connected to the LPS, and if so what size conductor should be used.

Where an LPS is fitted, PV system components should be mounted away from lightning rods and associated conductors (see BS EN 62305). For example, an inverter should not be mounted on an inside wall that has a lightning protection system down conductor running just the other side of the brickwork on the outside of the building.

Where there is a perceived increase in risk of direct lightning strike as a consequence of the installation of the PV system, specialists in lightning protection should be consulted with a view to installing a separate lightning protection system in accordance with BS EN 62305.

§ 16.14 Metering

Any meters should be located where the consumer can readily observe it.

§ 16.14.1 Inverter Output Meter

As a minimum, metering at the inverter output should be installed to display/record energy delivered by the PV system (kWh). In addition it is highly recommended for instantaneous power output (kW) to be displayed. This will not only add to customer satisfaction it should lead to more effective fault detection. An approved kWh meter as detailed in the “Metering Guidance” document issued by MCS, connected to measure generation, will be required to facilitate payments of any financial incentives (e.g. Feed in Tariff payments).

§ 16.14.2 Building Export Meter

Although not directly part of the PV system, where required in order to enable payment on exported electricity, an approved kWh export meter with appropriate reading capabilities may be required. The appropriate Energy Supplier should be contacted to find out any particular requirements and to arrange for its fitting.

§ 16.15 Module Requirements

§ 16.15.1 Module Requirements

- IEC 61215 in the case of crystalline types
- IEC 61646 in the case of thin film types
- IEC 61730 - Photovoltaic (PV) module safety qualification
- Modules must also carry a CE mark
- Modules must be certificated and listed on the MCS product database.

§ 16.15.2 Additional Requirements

The use of Class II modules is generally recommended, and strongly recommended for array open-circuit voltages of greater than 120 V.

The PV installer must be able to demonstrate such compliance for all relevant projects. MCS012 or MCS017 (as relevant) may assist in demonstrating such compliance.

With pitched roofs, products must have been tested and approved to MCS012 (test procedures used to demonstrate the performance of solar systems under the action of wind loads, fire, rainfall and wind driven rain).

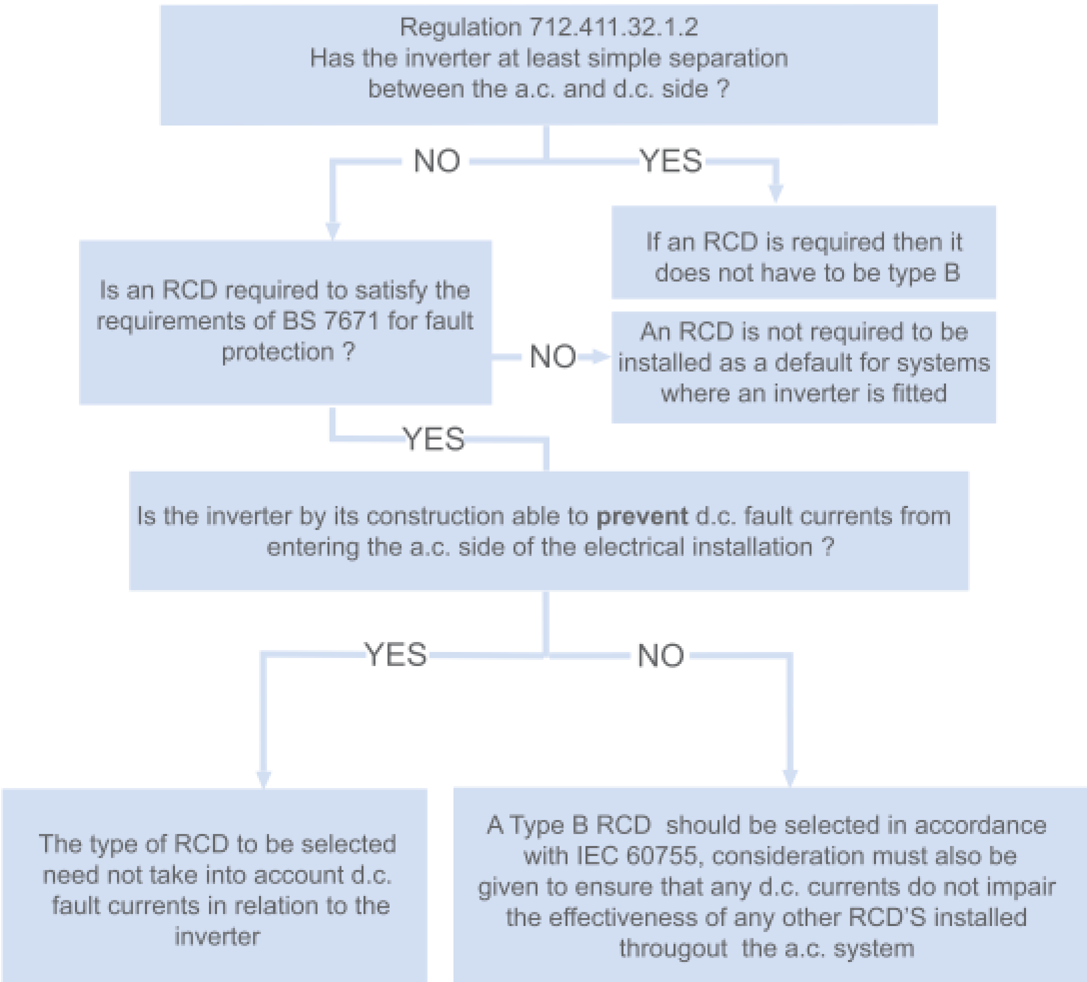
With bespoke building integrated modules, products must have been tested and approved to MCS017 Product Certification Scheme Requirements: Bespoke Building Integrated Photovoltaic Products.

§ 16.16 Residual-Current Device

Where an electrical installation includes a PV power supply system that cannot prevent d.c. fault currents from entering the a.c. side of the installation, and where an RCD is needed to satisfy the general requirements of the electrical installation in accordance with

BS 7671, then the selected RCD should be a Type B RCCB as defined in IEC 62423. Where any doubt exists about the capability of the inverter to prevent d.c. fault currents entering the a.c. side of the system then the manufacturer shall be consulted.

§ 16.16.1 RCD Decision Tree



§ 16.16.2 Types of Residual Current

Supply	Form of Residual Current	Recommended type of symbol AC	A	B
Sinusoidal A. C.	Suddenly applied Slowly rising	✓	✓	✓
Pulsating D.C.	Suddenly applied Slowly rising		✓	✓
Smooth D.C.				✓

§ 16.17 Roofing and Cladding Works

In all cases it is expected that the manufacturers' fixing instructions are followed with respect to wind loading.

§ 16.17.1 In roof products (eg PV tiles)

All fixing and flashing components used to mount and make weather-tight the solar roofing product must be packaged and listed as part of a complete kit that includes the PV module. The MCS installer must ensure that the system is installed to comply with the manufacturer's instructions. The weather tightness of the PV system should be the same or better than the roof or cladding systems they are replacing and should not adversely affect the weather tightness of the surrounding covering.

§ 16.17.2 In roof mounting system

All fixing and flashing components used to mount and make weather-tight the PV system must be specifically approved to work together (e.g. supplied and listed as a kit of parts) and listed to work with either the named PV module, or listed as a universal type where PV module type is immaterial to the performance of the system. The MCS installer must ensure that the system is installed to comply with the manufacturer's instructions for both the mounting system and the PV module.

§ 16.17.3 Above roof mounting systems

All components used to mount the system must be specifically approved to work together or be listed as universal components. The mounting system must also be listed to work with either the named PV module, or listed as a universal type where PV module type is immaterial to the performance of the system. The MCS installer must ensure that the system is installed to comply with the manufacturer's instructions for both the mounting system components and the PV module. Systems attached to tile roofs should be designed and installed such that the fixing brackets do not displace the tiles and cause gaps more than naturally occurs between the tiles. Fixing methods must not subject roof coverings to imposed loads which may degrade their primary purpose of maintaining weather-tightness.

§ 16.17.4 Through Bolts

Tiles or slates removed for fixing a mounting bracket should be re-attached to include a means of mechanical fixing. Historically, some mounting systems on slate or tile roofs have relied on a simple "through bolt" approach. However, this fixing method has the potential for the fixing bolts or sealing washer cracking the slates/tiles beneath them. It can also present difficulties with ensuring the long term weather tightness and durability of the roof penetration. It is good practice to notch tiles when fixing a roof bracket

Through bolts shall only be used on tile or slate roofs where the following requirements are met:

- The bolt or flashing shall not transfer any load on the slates / tiles beneath.
- The system shall not rely on silicone or other mastic sealant to provide a weather-tight seal.
- The system must durably seal every layer of roof covering that is perforated by the bolt system.
- The system shall not rely on a sealing washer or plate that presses down on the slate/tile to ensure a weather tight seal.
- The bolt fixings shall not be into battens .

§ 16.17.5 Roof Underlay

The roof underlay should be inspected for damage during installation works. Any damage should be repaired or the underlay replaced as necessary. Damaged underlay will not provide an effective weather and air barrier and can affect weather tightness and the wind loads imposed on the roof cladding. Site work should include verification to confirm that all the design requirements have been satisfied and that the roof covering has not been adversely affected by the installation work.

§ 16.17.6 Placement

Unless specifically designed to do so , systems should be kept away from the roof perimeter. For a domestic roof, a suitable **minimum clearance zone** is around 40-50cm. The requirement to keep an arrays away from a the edge of a roof is suggested because:

- Wind loads are higher in the edge zones
- Keeping edge zones clear facilitates better access for maintenance and fire services

- Taking arrays close to the roof edge may adversely affect rain drainage routes
- When retrofitting systems, there is the potential for damage to ridge, hip, valley or eaves details.

Note: on many roofs a 50cm gap from the edge will still mean that PV modules are fitted in the “Edge Zone” as defined in BS EN 1991-1 where higher pressure coefficients need to be implemented due to the higher imposed wind loads.

§ 16.17.7 Other

Cable penetrations through the roof should not affect the weather tightness of the roof and should be durably sealed to accommodate the movement and temperatures expected. The use of a purpose-made product is an example of a durable means to achieve this. Cable penetrations through underlay should be achieved using purpose-made products or, if taken through a lap in the underlay, the cable should be carefully routed, clipped and tensioned so as to leave a minimal residual gap in the underlay lap joint.

Thermal expansion should be considered when installing larger arrays. The module and mounting system manufacturer should be consulted to determine the maximum array width and continuous rail length that can be permitted without the need for an expansion gap.

Some PV array mounting systems rely on securing the array to the **metal roof cladding**. In such circumstances, the adequacy of the roof covering to transfer all additional loads back to the supporting structure should be verified. This should include consideration of all elements of the roof construction that could be affected by the additional loading. Calculations will include consideration of the array configuration (pitched or parallel to the roof) and the type, quantity and locations of PV array fixings.

§ 16.18 Safety

§ 16.18.1 Main Safety Issues

- The supply from PV modules cannot be switched off**.** A temporary warning sign and barrier must be posted during installation See requirements of Regulation 14 of Electricity at Work Regulations 1989.
- PV modules are current-limiting devices, so fuses are not likely to operate under short-circuit conditions.
- PV systems include d.c. wiring, with which few electrical installers are familiar.
- PPE (Personal Protective Equipment), working at height, manual handling, handling glass and CDM regulations.

§ 16.18.2 Details

Undetected fault currents can also develop into a **fire hazard**. Protection can be achieved only by both a good d.c. system design and a careful installation.

Use **insulating gloves and tools**, insulating materials for shrouding purposes, and appropriate personal protective equipment. Working at night reduced PV output. Covering an array is an alternative method. This introduces practical problems of keeping the array covered and protecting it from the weather.

A charge may build up in the PV system due to its distributed capacitance to ground making an additional **shock hazard**. This is more prevalent in amorphous (thin film) modules with metal frames or backing. In addition to insulated tools, ensuring a layer of insulation exists between the worker and any conductive surfaces (such a s a metal roof) can help mitigate this risk.

§ 16.19 Sequence of Works

All d.c. wiring should if possible be completed prior to installing a PV array. This will allow effective electrical isolation of the d.c. system (via the d.c. switch-disconnector and PV module cable connectors) while the array is installed; and effective electrical isolation of the PV array while the inverter is installed.

This should be carried out in such a way that it should never be necessary for an installer to work in any enclosure or situation featuring simultaneously accessible live PV string positive and negative parts.

§ 16.19.1 Sequence

- d.c. switch-disconnector and d.c. junction boxes
- String/array positive and negative cables - from the d.c. disconnect/junction box to either end of the PV string/array
- PV array main cables from d.c. switch to inverter

§ 16.19.2 Details

While the installer will be handling live cables during the subsequent module installation, because the circuit is broken at the d.c. switch-disconnecter, there is no possibility of an electric shock current flowing from the partially completed PV string. The maximum electric shock voltage that should ever be encountered is that of one individual PV module.

Where it is not possible to pre-install a d.c. isolator (eg a new-build project where a PV array is installed prior to the plant room being completed), cable ends/ connectors should be put temporarily into an isolation box and suitably labelled (see DC Junctioning).Cables are to be well supported, especially those cables exposed to the wind. Cables must be routed in prescribed zones or within mechanical protection, fully supported / cable tied (using UV stabilised ties) and they must also be protected from sharp edges.

§ 16.20 Shade Factor

§ 16.20.1 Analysis Method

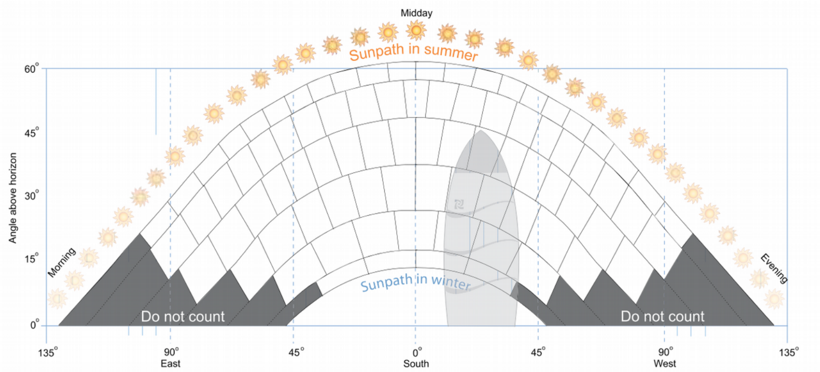
For systems connected to multiple inverters, or a single inverter with more than one MPP, it is acceptable to do a separate calculation of SF for each sub array.

Stand as near as possible to the base and centre of the proposed array, e.g. through an upstairs window, unless there is shading from objects within 10m (e.g. aerials, chimneys, etc.), in which case the assessment of shading must be taken from a position more representative of the centre and base of the potentially affected array position.

Looking due south (irrespective of the orientation of the array), draw a line showing the uppermost edge of any objects that are visible on the horizon (either near or far) onto the sunpath diagram

Once the horizon line has been drawn, the number of segments that have been touched by the line, or that fall under the horizon line shall be counted, in the following example you can see there are 11 segments covered or touched by the horizon line.

The total number of segments are multiplied by their value (0.01) and the total value shall be deducted from 1 to arrive at the shading factor.



§ 16.20.2 *Close Objects*

As noted previously, shading from objects adjacent to the array (for example: vent pipes, chimneys, and satellite dishes) can have a very significant impact on the system performance. Where such shading is apparent, either the array should be repositioned out of the shade zone, or where possible the object casting the shade should be relocated.

In addition, any objects on the horizon diagram that are 10m or closer to any part of the array, b. shall have a shade circle added to the diagram to reflect the severe impact that these items may have on the array performance. Where there are multiple objects within 10m, then multiple circles shall be drawn – one for each object. The shade circle shall have a radius equal to the height of the object. The shade circle should be located so that the apex of the circle sits on the highest point of the shade object.

§ 16.20.3 *Warning*

Shade assessments should include the phrase: “This shade assessment has been undertaken using the standard MCS procedure - it is estimated that this method will yield results within 10% of the actual annual energy yield for most systems.”

§ 16.21 String Fuses

§ 16.21.1 *Overcurrent*

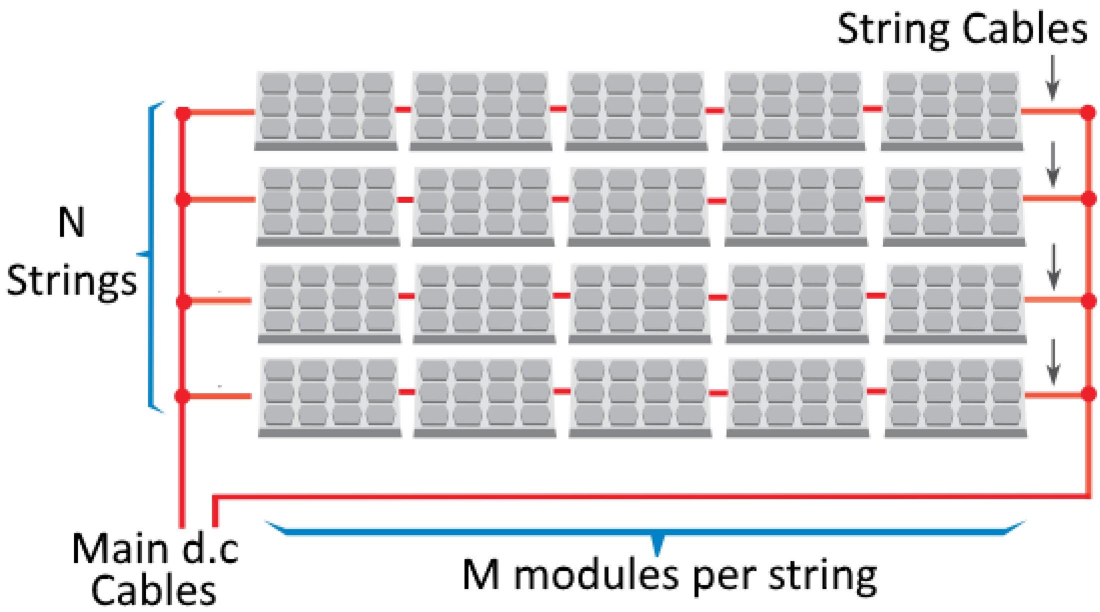
String fuses are required in both the positive and negative legs of the string cabling. For a system of N parallel connected strings, the maximum module reverse current to be experienced under fault conditions is: I_R = (N – 1) × I_{sc}

Hence, overcurrent protection is required where this value is greater than the module maximum series fuse rating. Fuses should not be mounted in such a position where their rating may be compromised by the build-up of heat from solar gains. The use of **MCBs (miniature circuit breakers)** is permissible provided they meet the string fuse criteria and are rated for use in an inductive circuit and will operate for currents flowing in either direction through the device.

String Fuse Operating Parameters

- V_{oc}(stc) x M x 1.15
- $I_n > 1.5 \times I_{sc}$
- $I_n \leq 2.4 \times I_{sc}$
- $I_n \leq$ Maximum series fuse value
- The string fuse must be of a type gPV

Where I I_n is the operating current, M is the number of modules per string, and N is the number of strings.



§ 16.21.2 *Special Circumstances*

For **small systems** where it is determined that fault currents do not present a risk to the modules, only the string cables and connectors need to be considered. A common approach in this case relies on oversizing string cables & connectors - such that they may safely carry the maximum possible fault current. Such a method does not clear the fault but simply prevents a fire risk from overloaded cables.

Where the inverter is of such a design that it has **multiple MPPT** inputs and the design does not allow fault currents to flow between these inputs, each MPPT input may be treated as a wholly separate sub-array for the purposes of deciding whether string fuses are required.

Also, See Blocking Diodes

§ 16.22 Surge Protection

All d.c. cables should be installed to provide as **short runs as possible** and positive and negative cables of the same string or main d.c. supply should be installed together, avoiding the creation of loops in the system. This requirement includes any associated earth/bonding conductors. Long cables (e.g. PV main d.c. cables over about 50 m) should be installed in earthed metal conduit or trunking, or be screened cables such as armoured.

Most grid connect **inverters** have some form of in-built surge suppression; however discrete devices may also be specified.

Note: These measures will act to both shield the cables from inductive surges and, by increasing inductance, attenuate surge transmission. Be aware of the need to allow any water or condensation that may accumulate in the conduit or trunking to escape through properly designed and installed vents.

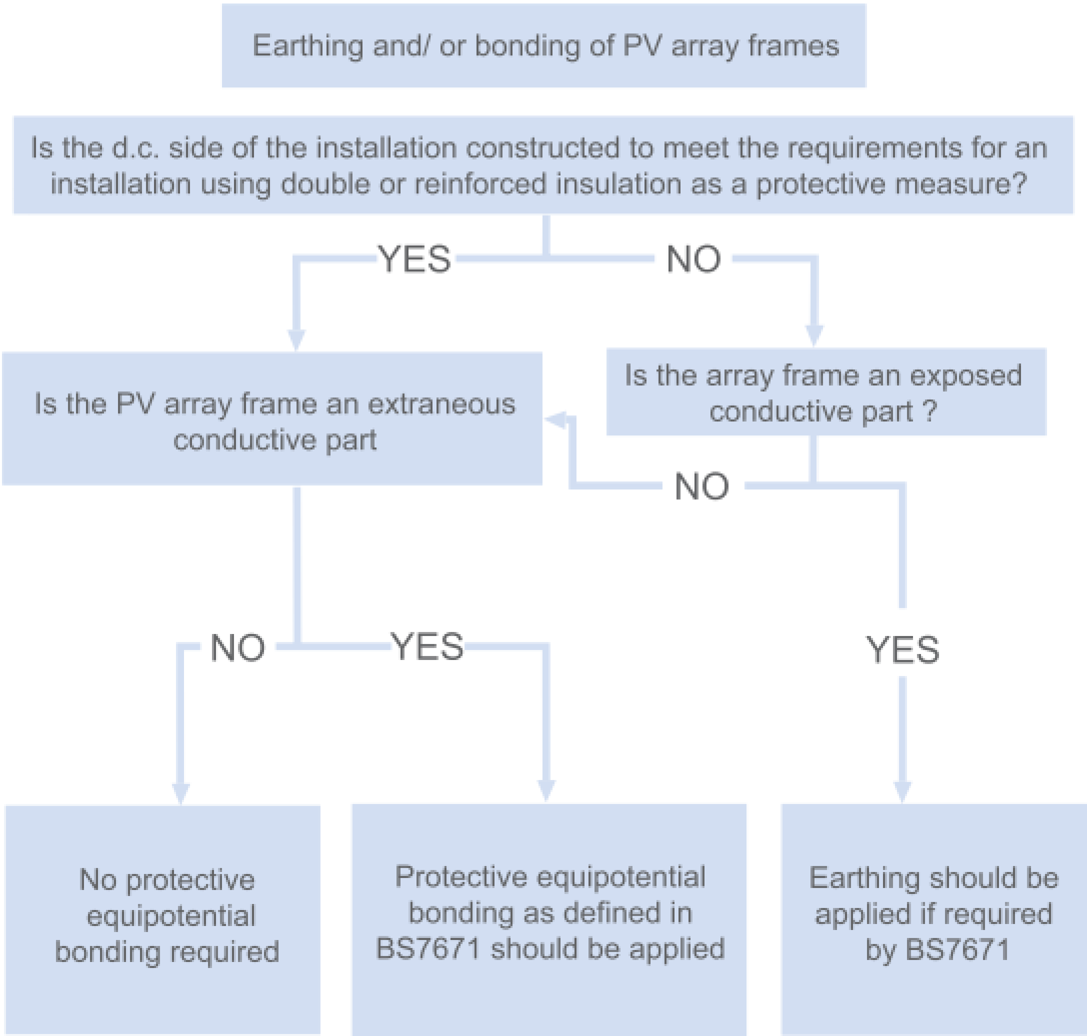
§ 16.23 Temperature Effects

Module temperature – An increase in module temperature results in a decrease in performance (eg 0.5% per 1°C above stc for a crystalline module). Sufficient ventilation must be provided behind an array for cooling (typically a minimum 25mm vented air gap to the rear). For building integrated systems, this is usually addressed by the provision of a vented air space behind the modules. On a conventional pitched roof, batten cavity ventilation is typically achieved by the use of counterbattens over the roof membrane and by the installation of eaves and ridge ventilation.

§ 16.24 Protective Equipotential Bonding

§ 16.24.1 Determining PEB Requirement

Protective equipotential bonding (PEB) is a measure applied to parts of the electrical installation which, under fault conditions may otherwise have a different potential to earth. By applying this measure the risk of electric shock is limited as there should be little or no difference in voltages (potential difference) between the parts that may otherwise become live. These parts are categorised as either Exposed-Conductive-Parts or Extraneous-Conductive-Parts



The frame of the array has to be assessed as to whether it is likely to introduce a potential into the installation. This aim of this assessment is to find out if the frame has any direct contact with ground that would make it introduce a potential. The details on carrying out these tests are best given in the IET BS 7671 Guidance Note 8 Earthing & Bonding and this should be referred to before undertaking a test

To find this out a resistance test should be carried out between the part in question (the array frame) and the MET of the building. Where the value recorded is greater than 22kΩ (most cases) the part can be considered to be isolated from earth and NOT an extraneous conductive part. If the reading is less than 22kΩ, then the part is considered to be extraneous and **requires protective equipotential bonding** as required by BS 7671.

§ 16.24.2 Roof Installations

Where the array frame is mounted on a domestic roof or similar, the likelihood of the frame being an extraneous-conductive-part is very low - due to the type and amount of material used between the ground and the roof structure (which will mainly be non-conductive). Even in the case of an array frame being mounted on a commercial building where mostly steelwork is used, it is likely that the frame will be either isolated, and therefore not required to be bonded, or will be bolted to the framework or steelwork of the building which will often be sufficient to maintain bonding continuity and a sufficiently low enough resistance to consider it to be bonded through the structure itself.

§ 16.24.3 Ground installations

Careful consideration needs to be given to systems that are ground mounted as they may initially appear to be an extraneous-conductive-part. However, as they are usually a good distance away from the earthed equipotential zone, by bonding them you may well be introducing a shock risk that wasn't there initially, and in the case of an installation supplied by a TN-C-S (PME) supply you may be contravening the supply authority's regulations (ESCQR 2002). In most cases these installations wouldn't require bonding – in such cases the designer must make an informed decision based on the electrical design of the entire installation, not just the PV system in isolation.

§ 16.25 <u>Wind Load Calculations</u>

§ 16.25.1 Introduction

The manufacturer's instructions should always be observed when designing a PV array mounting structure. In particular, attention shall be paid to the clamping zones as prescribed by each manufacturer as these will often vary. For each site the imposed wind and snow loads should be derived using the procedures within Eurocode-1.

§ 16.25.2 Pressure Coefficients

- For PV arrays that are mounted above, and parallel to, an inclined roof where there is a clear gap between the array and the roof - the pressure coefficients shall be taken from BRE digest 489 or from recognised test data commissioned for the specific purpose of determining the wind loads on solar systems.
- For flat roof systems - the pressure coefficients shall be taken from BRE digest 489 or from recognised test data commissioned for the specific purpose of determining the wind loads on solar systems.
- For roof integrated, nominally airtight systems - the pressure coefficients shall be taken from Eurocode-1.
- For roof integrated, air permeable “PV tile” type systems - the pressure coefficients shall be taken from BS5534 and treating the PV array as roof tiles

In determining the appropriate pressure coefficient to use in calculations, the location of the PV array on the roof needs to be determined as some, or all, of the array may be in the “Edge Zone” as defined in BS EN 1991-1. Pressure coefficients for the Edge Zone will be higher than those in the Central Zone of the roof. BRE digest 489 and the other sources listed above include pressure coefficient values for both Edge and Central zones.

A **safety factor** of 1.35 should be applied to the derived wind and snow loads and a factor of 1.0 to the dead load (self-weight). Load calculations shall be undertaken by a suitably competent person.

§ 16.25.3 Array Fixings

Check PV array fixings for withstanding dead load and wind uplift loads as calculated.

- For systems approved to MCS012 - ensuring that the imposed loads are within the range specified by the product manufacturer (and then installing according to the manufacturer's instructions)
- Using fixing data from Eurocode 5 - design of timber structures
- Using fixing bracket test data

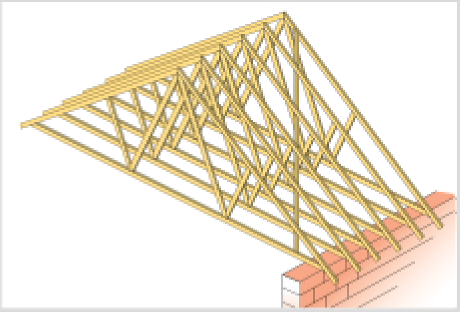
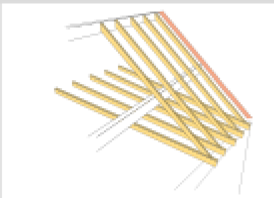
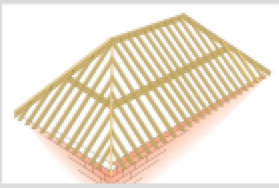
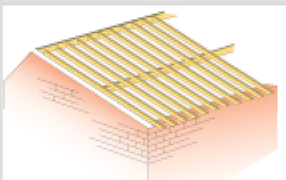
Note: Many standard above roof systems for pitched roofs suggest a screw layout that conflicts with the requirements of Eurocode 5 to keep fixings a certain number of screw diameters away from the rafter edge and each other. In such cases one solution is to fix the mounting bracket to a timber noggin fitted between the rafters. Alternatively, the fixing resilience can be determined from test data.

§ 16.25.4 Roof Structure

The roof structure itself shall be checked to ensure it can withstand the imposed loads as calculated. This is to include a site inspection. Some possible problems include the following.

- Signs of structural distress
- Signs of post construction modification (e.g. removal of timbers, notching, change of roof covering),
- The roof pitch is particularly shallow (under 30°)
- The roof design has increased potential for snow build-up (e.g. dormers, valleys, parapets etc)

If the type of construction is not detailed in the table below or if there is any doubt whatsoever then a qualified structural engineer shall be consulted.

Diagram	Construction Type of Roof	Typical Methodologies
Roof constructed from Timber Trussed Rafters 		Method 1: Assuming a typical design **dead load** of 0.785kN/m², deduct the load of the existing roof covering to give the maximum allowable residual load available for the solar array.
		Method 2 (not generally applicable where the roof pitch exceeds 60°): Assuming a typical **design imposed load** of 0.75kN/m2, deduct the likely snow load for the location taken from Eurocode-1 (BS EN 1991-1) to give the maximum allowable residual load available for the solar array.
	Traditional cut roofs constructed from timber rafters/purlins - gable ended	Calculate the maximum dead load for the rafters and purlins using the TRADA Span tables (2nd or 3rd Edition), deduct the load of the existing roof covering to give the maximum allowable residual load available for the solar array.
	Traditional cut roofs constructed from timber rafters/purlins – with hips and/or valleys	Consult a structural engineer.
	Asymmetric duo-pitched roofs constructed from rafters and purlins	Consult a structural engineer.

§ 17 Appendix H: Solar Thermal Reference

This guide is based primarily on *Solar water heating systems – guidance for professionals, conventional indirect models* [2]

§ 17.1 About

The information in this solar thermal guide is based on “Solar water heating systems – guidance for professionals, conventional indirect models” published by the Energy Saving Trust in 2006 with assistance of the Solar Trade Association. This information is for general guidance only and does not replace professional training. The practices outlined in this guide are based on the climate of the UK.

§ 17.2 Auxiliary DHW Heat Sources

Solar water heating is almost exclusively used to pre-heat DHW and not for space heating. Auxiliary heating is required because of the variable nature of solar irradiation through the day and the seasons. Auxiliary heat sources are fitted downstream of the solar pre-heat storage in order to allow the variable temperature of the pre-heated water to be best controlled. This placement also ensures that the auxiliary heat sources do not interfere with heat transfer from the primary circuit. An automatic gas/oil/electric auxiliary heat source downstream of a solar pre-heat store should preferably be controlled with a temperature interlock. In particular, when the stored, solar heated water has reached the intended target temperature, then the auxiliary heat source should automatically switch off and not be called to add extra heat above the target temperature.

Many DHW appliances require specialist knowledge and inspection before their suitability for solar pre-heating can be determined.

Normally the best whole system performance is achieved by complete replacement of existing DHW heat sources to ensure correct integration. This is the usual choice where the existing DHW is provided from a stored water arrangement. This also has the advantage that best practice for DHW provision can be achieved at the same time. Where the DHW source is a water store that is integrated with another device (such as a combi boiler) or fully instantaneous (such as an electric shower), then it is more common to design a system which retains these appliances.

New build: There is a range of ‘solar-ready’ DHW generators that can be installed in new dwellings independently of a solar primary system. These may include twin-coil stores that combine pre-heat and DHW into one unit; the lower solar coil is either left unconnected (as with an electric based store) or it is temporarily connected in series with the top boiler coil with the advantage of a rapid re-heat. However it is more common to fit a coherent and complete functional solar system with DHW generator simultaneously.

Existing: It is essential to confirm, by on-site test, that existing DHW generators are capable of achieving 60ºC at all foreseeable rates of secondary flow. Using a thermometer and weir gauge, the rate of various DHW flows can be measured against temperature at the outlets to establish the ability to sterilise to 60ºC.

§ 17.3 Collector Access

Access to the collector location will be required during installation, at future inspections and for maintenance. Typical obstacles include house-width conservatories, power/phone lines, porches, dormers, etc. since safe access methods can be obstructed both at low level or high. The requirement for cleaning can normally be expected to be a low priority at collector pitches of greater than 20 degrees, but should be considered in exceptional conditions. Availability of skylights of sufficient size can simplify future inspections.

Critical solar system components such as pressure safety valves should not be located in inaccessible locations, particularly if the maintenance regime requires these to be inspected.

Other workers who may visit the roof in the future could also be considered i.e. repairs to the roof, TV aerials, and chimney sweeping. Purpose built, non-corrosive steps are commercially available and are designed to provide permanent access on to roof pitch. An alternative, especially for flat roofs, is a cable fastening line for personal harnesses.

New build: Where thick layers of ceiling insulation are expected in roof voids behind the collector location, a walkway can be constructed above the insulation.

Existing: A site visit is required in order to inspect roof voids, the roof condition and clearances for equipment. Externally, the terrain should be checked for stability as well as above for loose roof tiles and overhead cables, etc. Heights of over two storeys should be approached with particular caution.

§ 17.4 Collectors

§ 17.4.1 Structure

The absorber usually has a translucent cover which allows light in and reduces heat losses from convection. An insulated enclosure provides structural integrity and reduces losses from conduction. Connectors allow fluid from the primary loop to circulate and control heat transmission from the collector into the dwelling. Collectors are either flat or tubular.

§ 17.4.2 Lifetime

The collector is subject to extremes of weather. During high irradiation periods, if there is no heat extraction, an absorber will normally stagnate between 150°C and 300°C. The absorber will then contain super-heated fluid or vapour at a pressure of up to 6 six times atmospheric pressure depending on the safety limiting devices. A collector should be able to survive these conditions, without specialised maintenance, for over 20 years.

§ 17.4.3 Performance

BS EN 12975 sets out procedures to test durability and reliability under extreme conditions, and provides a measure of energy performance. When an EN 12975 test report is published by a manufacturer, the CO_2 mitigation potential and safe design of a proposed system can be easily assessed and calculated. A collector should be tested and independently certified to EN 12975 in respect of durability, reliability and performance.

Performance is measured by EN 12975 by means of a plot of efficiency versus temperature difference. The test also gives an indication of the variance due to the angle of incidence and the thermal inertia. These results can be used directly in predictive software and other calculations which assess monthly or annual performance. To allow a collector to receive optimum irradiance, it is best located on the roof to avoid localised shading.

The amount of energy collected is largely determined by the area and efficiency of a collector, and it is important to be clear whether the gross (full) or net (absorber) area is being referred to when making comparisons. Collector efficiency varies according to temperature. Even a collector that is 85 % efficient when cold will in most circumstances have an average conversion efficiency of around 60 % due to heat losses. Further losses (from transmission, storage, and distribution) will reduce overall system efficiency to below 50 %. A reflector can artificially enlarge the aperture area, but it only works effectively in direct sunlight. In addition, the highly polished surfaces can quickly tarnish and fade in humid UK conditions.

§ 17.5 <u>Combined Stores</u>

It is common that solar pre-heat storage is combined with such heat sources into a single store, usually termed a ‘twin coil’ cylinder. An electric immersion element located in the top half of the cylinder is often used for occasional or emergency back up. The volume of the store shall be measured below the bottom of the lowest back-up element down to the lowest element of the solar primary. Physical separation offers a more robust method of securing the essential solar pre-heat volume necessary for efficient solar collector performance.

In a combined cylinder a small extra volume becomes available for solar storage in the upper part as the stored fossil fuel heated water is used up in a typical household. It is important that the ‘hot-top’ of a combined store is not purposely depleted during the day as comfort levels or bacterial-cleansing ability may be reduced. Where a combined store is used horizontally, there can be up to 40% loss of solar storage compared with one of similar size placed vertically. According to CEN/TC 228, where an existing DHW store is modified to accept solar storage or any other heat sources are present, the useful solar storage additional to the dedicated pre-heat storage volume is that indicated below.

Type of auxiliary heat	Auxiliary storage accessible for solar storage (per cent)
Permanently switched on	Less than 10
Overnight (off-peak)	30
Timed twice daily	30
Emergency or hygiene de-stratification auxiliary heat	70

§ 17.6 Commissioning

Commissioning is the point at which the responsibility of installed equipment is given to the end-user. This may be different from a change of legal ownership. A signed certificate is handed over to the user that certifies the equipment is safe, legal and fit for use in its intended purpose. Key safety and performance parameters on a checklist are confirmed as operational.

The values and tolerances of any variable or adjustable parameters are entered to enable future service personnel, or the user, to verify performance and safety. There may be more than one certificate if individual items can function separately i.e. hot water vessels.

A commissioning engineer must be a competent person who can personally testify by signature and date that the equipment is commissioned. Such a person should be suitably informed and trained. They should be properly and regularly assessed to a high standard.

It is intended that commissioning certificates will be a relevant part of the Government’s proposed ‘Home Information Pack’ (HIP). Where energy-monitoring equipment is fitted, such as heat meters or flow meters, then on-site sensor matching and calibration may also be required.

§ 17.7 Controls and Sensors

A simple, single thermostat is not suitable for controlling SDHW since this does not compare the temperatures of the collector and its store. Sensors for solar system controls, such as a DTC, have to display good accuracy (± 1.0ºC) across a wide measurement range whilst maintaining a good thermal contact with the fluid being measured. They should be insulated against change in ambient temperatures and firmly clamped to prevent accidental displacement. They should also be responsive to rapid changes, and should ideally be placed in purpose-made pockets immersed in the fluid. A coating of instrument grease can be used to withstand ingress of moisture that can cause a sensor to fail.

The SDHW primary circuit should be controlled by a temperature-sensitive device accurately measuring the difference in temperature between the absorber and the pre-heat storage or heat exchanger. Advanced DTCs use temperature-linked speed control of the circulating pump to maintain higher efficiency heat transfer.

The **differential** is the difference between switching points or thresholds. This is adjusted for an individual installation according to the heat loss of the transfer circuit and heat exchanger configuration. A long distance between a collector and store would require a higher differential than a short run. The **hysteresis** is the difference in switching variance around a given point: this can differ according to the direction of movement of temperature (i.e. rising or falling around the switching point). It can be adjusted to avoid unnecessary short cycling or hunting of a pump. A typical differential would be between 5ºC and 10ºC, while the hysteresis would be between 2ºC and 5ºC.

§ 17.7.1 Required Sensors

Primary Circuit Fluid Levels

A pressure gauge, level mark or test-point in a primary vessel

Pressure

High pressure can be a safety hazard, low pressure reduces efficiency

Circulation Rate

This indicates sufficient heat extraction will occur

Temperatures

Absorber, pre-heat storage, DHW store

Irradiation Levels

Recommended, but not required

Warning Indicators

Audible or flashing indicator should enable a rapid diagnosis of the error and required action

§ 17.8 Heat Exchanger

A heat exchanger is normally placed between the collector primary loop and the solar store. Due to the predominately low temperature range of transfer, such heat exchangers need much larger surface areas than conventional exchangers. In all cases the net heat transfer should be at least 40W/K per m^2 of exchanger per net unit area of collector absorber (according to prEN 12977).

If a solar heat exchanger is placed adjacent to, or intertwined with, another heat exchanger, then unwanted (reverse) heat transfer can occur and the dedicated pre-heat volume will be diminished. A similar problem will occur where an electric immersion element is not sufficiently high enough or a secondary pump acts to circulate hot water downwards through the store.

Ideally, the collector return loop connection is made at the coolest part of the system, possibly adjacent to the store's cold feed. In a combined store, a physical division between different heat sources should be used in preference to a 'time-control' strategy relying purely on electronic devices.

§ 17.9 Insulation

As a rule, thermal solar energy is a useful, low carbon displacement for fossil fuels. Normally, solar thermal energy is stored for at least some time until required. Where long storage times of the heated water are required then the usability factor is low. The use of insulation and efficient methods of transferring heat will reduce losses, increase the displacement of fossil fuels and improve comfort. According to DTI Report SP 300275-3, solar stores that are poorly insulated can account for losses of over 15 % (of the useful energy produced annually) in addition to increasing the overheating risk for parts of the dwelling during summer.

The insulation of a solar pre-heat store should be at least equivalent to current best practice for conventional DHW stores. For existing best practice for DHW storage see CHeSS (HR6 note 9). Existing water and building regulations already set insulation levels for pipes in certain circumstances and prEN 12828 or BS 5422 provides further guidance. However, best practice would extend these levels to all internal solar primary pipes. Reducing pipe diameters can reduce heat loss from pipes but this should be done with care, to avoid increasing electrical parasitic pump losses due to increased pumping. All pipes of a solar primary system should be insulated to a conductivity no greater than 0.040W/mK and the thickness should be at least one and a half times the pipe diameter – or an equivalent heat loss measured at 50ºC.

Pipes that are not well insulated can unnecessarily add to the overheating of spaces during summer and present a risk of contact burns. Heat loss can also occur through air infiltration at pipe/roof penetrations and unwanted thermosyphoning of fluid in pipes from warm ambient air.

Insulation should be judged for its ability to withstand weather, ultra-violet degradation, maximum stagnation temperature and vermin.

§ 17.10 Isolation

As there is a significant risk of scalding or over-pressure, a SDHW system must be capable of hydraulic and electrical isolation from any pump and the pre-heat storage, to allow for periodic maintenance. The isolation mechanism, such as ball or gate valves, must not be able to accidentally isolate the collector from a route to safety devices. In particular, no valve must be placed so as to isolate a safety pressure release valve or expansion/drainback vessel. A solar primary system should include a clear and safe means of isolating a collector from the pre-heat store.

§ 17.11 Losses

Parasitic losses occur where energy is simultaneously used for other devices during the operation of the circuit. An example is a pump circulating the primary fluid from the collector. Parasitic losses are generally from electrically powered devices. **Standing losses** occur where the energy used for powering dependent devices is continuous regardless of whether heat energy is being transferred. Standing losses can be either electrical (e.g. safety temperature displays) or thermal (e.g. heat from a hot water store).The combined effect of electrical parasitic and standing losses can be a total loss equivalent to over 8 % of the total solar thermal energy.

§ 17.11.1 Loss Reduction

It is possible to reduce the parasitic losses by matching **pump power** to the minimum required for circulation, using variable speed inverter-driven pumps or putting insulation around the pump casing (where permitted by the manufacturer). The electrical input power of the primary pump in the solar system should preferably use no higher than 2 % of the peak thermal power of the collector. By using a differential thermostatic control (DTC) pump controller, it is possible to modulate pump speed in relation to temperature and minimise parasitic losses.

Certain heat losses from a solar water heating system are recoverable during the **space-heating** season. The recoverable part can be considered as 100 % if the component is installed in the heated space. Some 40 % is normally recovered if the pump is installed in an un-heated space but none if the component is installed outside. Therefore, the pump and its control device should be located within the normally heated space of the dwelling.

Where pipes and cables pass through the building’s insulated structure, these services should be designed to minimise risk of **air infiltration**.

§ 17.12 Losses (Night)

During the night, heat in warm water located near the solar circuit can easily rise via the primary pipes to a solar collector by natural convection (thermosyphon), forming a circulation loop within the pipes which is capable of completely cooling a solar pre-heat store overnight. Inadvertent triggering of a temperature control sensor in the solar collector can then switch on a pump, exacerbating the situation.

This circulation can be caused by:

- Warm ambient air heating the fluid in the pipes and causing thermosyphoning to the cooler collector.
- DHW heated from auxiliary fuel sources entering the solar primary.
- Solar heat, previously collected, re-entering the pre-heat store.
- Cold-feed for the store entering the primary.

A means of preventing reverse circulation should be provided, in both flow and return primary pipes, to avoid loss of stored heat. For fully flooded systems, anti-reverse circulation devices normally include a spring-loaded one-way check valve located in both the flow and return pipes. They should be located away from the collector to minimize high temperature exposure. These valves may require a bypass or drain-point to allow complete flushing/draining during installation and periodic maintenance. Drainback systems normally have no fluid remaining in the primary circuit once the pump has stopped. They must not be fitted with check valves in the circuit, but will instead rely on a downward drop in the pipes to a vessel.

On cloudless nights, the temperature of an absorber can fall below the ambient temperature due to black-body radiation, freezing of the absorber surface.

Under normal conditions the pump must not circulate heat if the collector is cooler than the solar storage. This is best prevented by using at least two temperature sensors, one fitted into the absorber and the other into the solar store. These must operate in conjunction with each other to permit pump circulation only when useful net heat can be gained. This forms part of an ‘interlock’ between the collector loop and the pump. A physical separation between auxiliary heat sources (downstream) and the solar circuit is also recommended.

§ 17.13 Maintenance and Documentation

§ 17.13.1 Documentation

Information relevant to the future owners of solar water heating equipment should be left on site. This should be in a dry, accessible, heat- and dust-free location, preferably adjacent to the pre-heat store or pump controller.

The **documentation** items should include:

- Full system installation instructions.

- User guide.
- Maintenance schedule.
- Decommissioning schedule.
- Schematic diagram.
- Commissioning certificate.
- Commissioning engineer’s contact details.

§ 17.13.2 Annual Inspection Checks

Most solar water heating primary systems will benefit from **annual inspection checks**. A user should not be put in danger in carrying out these checks. If a minimum competency is required to inspect, this should be clearly stated.

\An example list may include the following:

- Collector glazing is undamaged.
- Collector glazing is reasonably clean.
- Where visible, absorber paintwork or coating is sound.
- The roof fixings are firm and the roof covering satisfactory by visual inspection.
- Fluid levels in the cistern, vessel or pressure gauge checked against commissioned tolerances.
- Electrical controls and temperature sensors are operating sensibly.
- The circulating pump is operating without due noise.
- Pipework insulation is firmly in place.
- There are no condensation or damp spots, particularly around the pipework and fixings in the roof space.
- All safety and information labels are in place.
- The antifreeze should be tested at least every five years (depending on the type chosen). Some antifreeze products also require regular replacement. Regular de-scaling may be required for the heat exchanger surfaces.

§ 17.13.3 Pressure or Fluid Level Drop

If there is a significant d**rop in primary pressure or fluid level**, suspect one or more of the following:

- Overheating may have occurred during a period of hot weather if the circulation unintentionally failed or the system was incorrectly designed. When thermal energy is not being removed from the collector, the water temperature will rise; water volume and system pressure could increase beyond safety device limits. In some types of system, this could result in the release of hot water or steam from the pressure relief valve or the automatic/manual vent. When the system returns to normal operating conditions, the pressure will reduce due to the loss in fluid volume.

- If there is a leak in the system, it may require a drain down and repair/replacement of the faulty component(s).

§ 17.13.4 System Malfunction

The main reasons why some older solar water heating systems **malfunction** are:

- Frost damage to the collector due to degradation of antifreeze.
- Temperature sensors displaced from the correct position.
- Circulating pump seizure.
- Loss of fluid due to open vent evaporation, or slow leak often through automatic air vent.
- Sealed system expansion vessel has lost pre-charge.
- Residue from overheated antifreeze blocking pipes.
- Limescale blocking the collector, pipes or heat exchanger.

§ 17.13.5 Poor Performance

The main reasons why some solar water heating systems **perform poorly** are:

- Temperature differential between tank and panel wrongly set within solar controller.
- Pump control missing or malfunctioning.
- Another heat appliance interfering with transfer in DHW store.
- Missing or damaged insulation of pipes and store.
- Incorrect location of temperature sensors.
- Inadequate air removal from pipes.
- Incorrect pump speed.

§ 17.14 Occupant’s DHW Regime

The way DHW is used greatly affects the solar contribution, no matter what level of equipment is installed. Is the household likely to have a morning peak, evening peak or continuous all day demand? Will there be significant vacant periods i.e. holidays or during relocation? Continuous, even demands require less pre-heat storage, whereas often absent households require over-sized storage. High DHW use per person for example, with power showers or increased laundry use, can make best use of proportionally larger solar collectors. Certain hot water appliances may not accept pre-heated water e.g. washing machines or dishwashers. These are best eliminated from design calculations. A solar system can be designed for a high annual solar fraction or high usability factor (best value). Clients are best consulted and the results recorded.

The DHW usage pattern of a household should be anticipated before selecting secondary heating equipment.

New build: The intended occupancy and their DHW use can be derived from discussion with clients and use of standard references. Where unknown, DHW use at 50ºC per day can be assumed as (38 + 25N) litres per day where N is the number of occupants.

Existing: A site visit to inspect DHW appliances and a discussion with occupants would establish the intended DHW usage pattern.

§ 17.15 Over-pressure Protection

§ 17.15.1 Over-pressure

A safety device to control the risk of over-pressure in system components should be fitted. The pipe leading to it and the collector should be of rigid and non-deformable construction, without any possibility of restriction or closure by any other fitted component. A termination from a safety pressure device should be directed into a high temperature receptacle, an internal gully or else issue externally at ground level. High level termination from walls or on roofs could cause injury to people or animals below if the valve were to release scalding water and steam. Ideally, an expansion vessel large enough to hold the primary fluid contents of the collector plus the expansion volume of the system would prevent this release.

In the event of venting water, there is loss of usable energy contribution and of CO_2 mitigation. Also, user intervention might be required to restart operation. Primary systems can, however, be designed to automatically and safely resume after stagnation. Such systems conform to the principles of overheating protection in EN 12976 and can be termed inherently secure.

§ 17.16 Pitch and Orientation

The collector fixing surface can be a pitched roof, flat roof, vertical wall, balustrade or ground mount. Many UK roofs provide close to the optimum pitch, and with a reasonable leeway from south-east to south-west, losses of only 10 % of the annual energy yield are typical. This can be accommodated by collector 'oversizing'; alternatively , a loss of performance can be declared to the user.

Where an excess of 10 % less than optimum is predicted i.e. approaching east, west or on steep pitches, the customer should be informed in writing prior to commencing work that the suggested site is 'significantly less than optimum' and that an 'oversized' collector is recommended of at least 20 % greater absorber area.

In the case of an unfavourable pitch or orientation, collectors are available where the absorber can be rotated within the format of the collector glazing. This is frequently possible with glass tube formats where cylindrical absorber shapes add some advantage. Adjacent tubes should not overshadow each other and typically a maximum rotational gain of 20 degrees is available. The alternative of unequal spacer blocks, or additional frames on pitched roofs, is rarely cost effective.

For flat roofs or ground-mounted systems, a metallic frame can be used to achieve optimum positions; however structural loading should be carefully considered. The use of multi-position collector arrays can be considered where available locations are too small or unfavourable i.e. east/west pitches, although this would require separate and independent circulation controls to avoid unwanted loss of heat through the colder aspect.

Where a choice of pitch is available, consideration should be given to the build-up of dust on the collector surfaces. A nominal 5% loss of energy yield is expected in all conditions without cleaning: however this will increase at pitches of less than 20 degrees. In areas where high build-up is expected i.e. from sea salt, high density traffic or tree sap, the problem will be exacerbated with collectors set at a low pitch.

New build: The available pitch and orientation of collector locations can usually be derived from typical scale drawings. It may still be possible to design the building to optimise SDHW yield i.e. pitched and between south-east and south-west. Rooms-in-roofs can be constructed with purpose-built service routes from the solar collecting surface to the solar storage location. The use of pre-insulated and unjointed flexible metal pipe can be an aid in difficult locations.

Existing: A site visit using a compass and protractor will establish the best locations. Photographs accompanied by scale drawings can also be used.

§ 17.17 Pre-heat Storage

§ 17.17.1 Definition

The pre-heat store is the principal location where energy is delivered from the primary system. This is integrated with any other heat sources situated further ‘downstream’ in the DHW system. These additional heat sources top-up any temperature shortfall from the solar-generated pre-heat water before final distribution as DHW. Sufficiently sized pre-heat storage avoids excessive utilisation losses and reduces the frequency of stagnation, which in turn increases the life of components. The pre-heat storage is abbreviated as ‘Vs’ and is measured in litres. See both “Combined Stores” and “Separate Stores.”

§ 17.17.2 Sizing

To work correctly, there must be enough storage dedicated to the solar primary circuit that no other heating source will normally affect its operation. This refers to heat sources intended to contribute to average daily DHW demand (V); it does not mean manually-controlled sources used for occasional boost beyond mean daily DHW demand or automatic sterilisation routines. If an absorber is of the highest efficiency then, up to 100 litres per square metre of absorber for some collector types.

Test method prEN 12977-3 provides a measure of the energy performance of a solar store. This standard allows the CO_2 mitigation of a proposed system to be calculated and from this information the most suitable store for a given solar primary system can be selected. A store for secondary water pre-heated by a solar system should be tested and independently certified to prEN 12977-3 or equivalent.

The dedicated solar pre-heat storage volume (Vs) should be at least the greater of

(a) the anticipated average daily DHW demand; or

(b) 35 litres per net m^2 of absorber area.

The consequences of a small heat store is shown here:

Solar storage per litre of daily DHW used	Proportion of solar energy utilised
Vs / V	per cent
1.0 or more	100
0.9	98
0.8	95
0.7	92
0.6	89
0.5	86
0.4	82
0.3 or less	77 or less

§ 17.18 Pre-heat Storage Locations

For most dwellings, the notional extra physical space required for pre-heat storage is equivalent to the number of occupants multiplied by at least $0.05m^3$. This includes space for appropriate insulation and pipe connections. However, further space should be allowed for primary system controls and insulated pipes. Where a twin-coil store is used, the DHW store size is combined with the pre-heat store into one unit; this requires extra space of approximately 2.0m by 1.0m by 0.8m.

The solar pre-heat store must be located where it can readily connect with the solar collecting surface via insulated primary pipes and sensor cables. It should be within the normally heated area of the dwelling.

Generally, it is necessary to have an accessible mains electric power supply in the solar store location to allow the fitting of accurate temperature indicators. In addition, the store needs to be protected from frost. The anticipated weight of a pre-heat store is at least 60kg multiplied by the number of occupants. Accessibility for maintenance should also be considered.

New build: Pre-heat storage locations can easily be designed in a dwelling at its planning stage.

Existing: An on-site survey will be needed to establish if an existing airing cupboard is suitable. Particular care should be taken with floor supports. Unheated voids such as roofs should be carefully checked for future access, floor strength and frost protection.

§ 17.19 Risk of Bacteria

The solar pre-heat volume temperatures will vary through the year from as low as 5ºC in winter up to possibly 85ºC in summer. In this respect, pre-heated water should not be considered as fully treated for DHW use and should not enter the household distribution until it has been further conditioned for comfort and safety. There is an increased risk of bacteria growth at temperatures between 20ºC to 46ºC during prolonged periods without DHW draw-off. Special attention should be given to situations where cold water originates from unclean water cisterns (without lids) or where there are porous, suspicious or unknown fittings in contact with the water.

The risks can be minimised by:

- Reducing pre-heated storage to below twice the average daily hot water use.
- Using indirect primary circuits.
- Replacing old, poorly insulated DHW stores.
- Using electronic primary pump controls with programming targeted to achieve 60ºC storage.
- Reducing long lengths of uninsulated secondary pipework.

Irrespective of the above, reliable sterilisation is best achieved by ensuring pre-heated water passes through to another reliable heat source capable of sterilisation of unwanted bacteria. It should be noted that legionella bacteria can be expected to be killed within seconds at 60ºC.

It should be noted that the use of de-stratifying secondary pumps or an occasional back-up heat source within the pre-heat store could drastically reduce the solar performance and effectively de-rate the dedicated pre-heat store. To optimise solar efficiency, secondary circulation distribution is best implemented only in the DHW store. However, where a high risk of bacterial proliferation exists, the solar pre-heat store can be designed to be regularly sterilised, ideally at the end of the day to give the best chance for this to be achieved by solar. Such sterilisation should be accurately controlled by time and temperature in order to restore solar storage promptly.

§ 17.20 Risk of Limescale

The higher temperatures experienced in solar stores can mean that limescale becomes a significant problem. This can eventually reduce the performance and efficiency of the solar system. The problem varies from site to site and a skilled assessment is required before attempting to minimise the risk. When considering the use of products that are claimed to reduce limescale, thought should be given to the effects of varying future water quality, unexpected user intervention and any parasitic or standing electrical losses that may be required to operate such devices. Techniques to reduce heat exchanger temperatures have beneficial results in high limescale areas and can be more robust than additional devices such as water softeners. In severe cases, pre-heat solar storage can be limited to 60ºC through temperature control of the primary circulation or by increasing the size of heat exchanger. Similar effects can be realised by increasing the fluid content of the collector primary loop or increasing the primary circulation rate.

Direct solar primary systems are particularly prone to limescale within the absorber. An indirect circuit should always be considered as the first step to reducing the risk of limescale inside the absorber.

Where the cold water supply is expected to be above 100mg/l calcium carbonate average equivalent, written procedures for monitoring and cleaning areas likely to be affected by limescale should be given to the end-user. In particular, the likely risk of long term limescale formation in the pre-heat store and on the heat exchange surfaces should be considered. In potentially severe cases of limescale formation, the solar pre-heat exchanger should be made accessible for an annual cleaning procedure described in documentation left on site. Alternatively, the secondary solar pre-heat store should be capable of being accurately controlled to below 60ºC.

§ 17.21 Risk of Scalding

During hot weather, there are risks of scalding from solar heated water. This is why the temperature of secondary water from a solar pre-heat store should be limited before entering DHW distribution. Although a large pre-heat store can be used to reduce temperature peaks, further assurance is required to cover the more extreme conditions. A pump control on the primary circuit, or a thermostatic blending valve on the DHW distribution, is a necessary consideration. The controls should allow a commissioning engineer to choose from a range of options to suit the prevalent and future water conditions.

The outlet of a secondary solar pre-heat store should be capable of being accurately controlled to at least 60ºC with an adjustable safety control device. For vulnerable groups, temperatures above 43ºC particularly in baths will increase the risk of scalding. Scale deposition tends to accelerate rapidly above a temperature of 60ºC. Therefore a target temperature for a store should be carefully set taking into account local water quality. Maintaining a balance between bacteria safety, scald risk, water flow rates, and scale reduction requires careful design.

§ 17.22 Roof Coverings and Wind Loading

A key question concerns whether the solar collector will be located within or above the fixing surface. On a pitched tiled roof, for example, tiles can be removed and the collector set into the roof line, much like a typical skylight. Depending on the roof substructure, it may even be possible to achieve a flush finish not unlike patent glazing. The choice of 'in-roof' or 'above-roof' will greatly influence the choice of glazing and collector design since glass tube collectors are generally unsuitable for in-roof applications. Care should be taken that the flashing provided with a collector is compatible with localised roof coverings. In-roof applications invariably require hydraulic and sensor connections to the rear of the collector. Whilst this improves aesthetics, reduces heat loss and minimises vermin attack, there can be a downside where access to the underside is restricted (particularly with a room-in-a-roof or vaulted ceiling immediately below).

In above-roof installations, the combined structural loadings of wind and snow can create component loading varying from +2kN through to suction lift of -1kN. This compares to a static loading due to traditional roof coverings of a nominal +0.03kN/m^2. It is vital that the combined dynamic loadings of wind and snow are not channelled onto a fragile roof covering. Further considerations include allowance for thermal expansion, differential negative lifting on adjoining components, sufficient (over)lap of roof components, and the ability of the roof structures (i.e. rafters, purlins, trusses) to withstand the loadings.

For a pitched roof, a SDHW collector will require at least four mounting points, with loading taken through, and not onto, the roof covering – either to the rafters or via additional timber bearers using metallic brackets. Traditional timber battens or lath are insufficient to withstand the loading and are vulnerable to long term corrosion.

Prior consideration should also be given to the preferred route for hydraulic and control connections which are likely to require separate weather sealing. In all situations, care should be taken with materials adjacent to fluid-carrying components from the solar system, as these can be at full stagnation temperature (typically in excess of 150ºC).

With a flat roof or ground-mounted system, options include the use of ballast weight or fixing into the mounting surfaces. These may also be used in combination; however great care is required to not overload a sub-structure. A collector can be mounted horizontally in order to avoid excessive wind loadings on the rear of exposed A-frames. Some collectors allow the absorber to be internally rotated to a more efficient angle whilst appearing flat from a distance.

The following roof coverings require particular care in the choice of fixing method. A competent roofer and structural engineer may be required:

- Asbestos cement.
- Built-up felt, supported by wood-wool boards or insulation.
- Profiled metal supported on metal rafters.
- Sheet metal (lead, copper, zinc).
- Conservatory or greenhouse patent glazing.
- Wooden shingles.
- Single ply membrane.
- Thatch.

New build: An ideal location for a solar collecting surface would have a readily removable roof covering (e.g. tiles) for simple structural and pipe/cable access. A clearance gap of no less than two metres to each side of the intended collector position would give suitable working space during installation and permit ease of future maintenance. Consideration of interstitial condensation may be required where humid air is expected to rise towards the pipe entry location from the collector. Where a future solar collector is planned, purpose-made structural mounting points can be provided in advance, especially where the roof covering is not likely to be easy to remove.

Existing: A site visit is invaluable in anticipating existing damage to roof coverings and sub-structure. Where the roof structure has warped over time, difficulties can be experienced in integrating a rigid collector in-roof.

§ 17.23 <u>Secondary Storage Systems</u>

A secondary system receives energy from a primary system. It stores this energy and distributes it to the DHW appliances of the dwelling. It is essential to provide a sufficient volume of water to accept the solar energy whenever it is available. This will maintain the collector efficiency and predicted carbon dioxide savings. General guidance on hot water services can be found in BS EN 806. See “Pre-heat Storage,” “Combined Stores,” and “Separate Stores.”

The storage method varies greatly depending on:

- Available water pressure
- Existing DHW stores and DHW appliances
- Water quality
- Physical space available

§ 17.24 Secondary Water Pressure

The intended DHW pressure and type of cold feed must be determined early in the design process as certain choices greatly influence the formats of pre-heat storage and DHW generators. In particular, a choice between low pressure (cistern-fed) or mains pressure should be made early. The peak flow-rates of showers and the potential effects of thermostatic mixing valves need to be taken into account. Private water supplies require extra care, in the light of potential summer droughts and intermittent loss of supplies. The integration of solar heating into a dwelling should not unduly impair the secondary water pressure.

New build: Secondary water pressure can be determined for a dwelling at its planning stage.

Existing: A site inspection and measurement of dynamic water pressure will be needed. Specialised tools may be required such as a weir gauge, pressure gauge, stopwatch and measuring jug. By examining the water pressure at one tap within the dwelling while using water from another, it is possible to compare the time to fill a given volume (this gives the flow rate) with the pressure maintained elsewhere in the house.

§ 17.25 Separate Stores

§ 17.25.1 2 tanks

A water store heated by an auxiliary source, such as a boiler, can be located separately from the solar store. When DHW is drawn off, pre-heated water moves into the base of the boiler store. A thermostat controls the boiler (and immersion) and responds to the solar heat when there is a draw-off. The boiler store can remain hot to ensure comfort and sterilisation. Diversion valves that automatically omit the boiler cylinder can allow untreated water into the DHW distribution and put the user at increased risk from scalding and bacteria. Pumped circulation between the stores based on a comparative temperature control (e.g. differential thermostatic control (DTC)) could be used, providing the natural stratification of the pre-heat store is not lost.

Page 15 Diagram

§ 17.25.2 Direct DHW heaters

An auxiliary heat source can also operate directly on the water, for example with a combi boiler, multipoint, single point or electric point-of-use appliance. In these cases, the auxiliary heat can be considered downstream from the separate solar input. When DHW is drawn off, pre-heated water moves into the normally cold feed DHW generator. This method must be considered with great care, as many of these types of appliance are not designed for pre-heat. Incorrect pre-heating can lead to the appliance working inefficiently, overheating and even result in component failure. A thermostatic blending valve may be required for protection on either side of the appliance. Some appliances may display a mark to indicate suitability for pre-heating. During short draw-off volumes, correct thermostatic control requires that the appliance does not switch on or fire unnecessarily when the solar store is already hot.

Diversion valves that automatically omit the DHW generator, when the solar water is hot enough, can allow untreated water into the DHW distribution and put the user at increased risk from scalding. They can also inadvertently block important safety features and so should only be included with full approval of the appliance manufacturer. Where correctly fitted, divert valves can increase the appliance performance during high solar gains.

Page 16 diagram

§ 17.25.3 Thermal stratification

Thermal stratification is the natural layering of buoyant warmer water over cold. Its effects are desirable in pre-heat storage in order to maintain effective heat transfer from the primary loop. For the same volume, the effect is most pronounced in tall, thin stores with an elevated height width ratio. Stores in horizontal format have poor stratification and therefore are not recommended for solar storage.

With careful arrangement of exchange surfaces and choice of materials, the mixing sometimes caused by thermal eddies, cold feed inrush and cylinder wall conduction can be reduced in stores of certain formats. These may use extra vertically stacked coils, tubes or internal separators to encourage the ‘chimney’ effect of buoyant warm water.

Some pump controls can be programmed to delay circulation and increase the primary loop temperature before loading, which will encourage stratification. The thermal stratification of DHW stores should be considered separately from that in solar pre-heat stores. A test method to measure solar store stratification is given in prEN-12977-3.

§ 17.26 Shading

There should be no shading. In predominantly shaded locations, 50% of the total solar irradiation can be expected to be lost. Partial shading, such as shadows of trees, chimneys, higher buildings, etc. can also have adverse effects with localised overheating of the fluid in a collector – or a loss of heat transfer if the sensors are shaded.

Where shading is unavoidable, a shadow greater than 10% of the collector area passing completely across the collector in less than an hour between May and October can be considered acceptable. However, if the shadowing lasts in excess of two hours, the customer should be informed in writing – prior to commencing work – that the suggested site is ‘significantly shaded’ and that an ‘oversized’ collector is recommended, at least 20 % greater in absorber area than in an unshaded location.

Consideration should be given to a controller capable of switching on the pump for a fixed, limited period once every 30 minutes, subject to temperature control. This can overcome unfavourable sensor positions during shading. Remember that the track of the sun will vary daily from the horizon, peaking to a zenith at midday GMT. In addition, the angle of the zenith will alter significantly from winter solstice to summer. Allowance for the future growth of nearby trees should be considered.

New build: Shading can be complex to model, although many design software packages now allow shading to be readily calculated. Ideally, the design would ensure a layout and orientation that minimises shading risks and would normally avoid shading that required oversizing. Dedicated commercial software packages for SDHW designers are available. A simple manual method uses graph paper to represent the horizon from east to west with objects plotted in size pro-rata to their distance from the collector position. The remaining area of sky shown on the graph paper gives an indication of direct irradiation.

Existing: A site visit is a prerequisite for assessing shading. A compass and a transparent sheet indicating the tracks of the sun seasonally and daily allow a thorough examination even in cloudy conditions. Every effort should be made to take the shading survey at the collector position, in order to avoid parallax errors arising from estimates made on the ground or at upper windows. Anecdotal comments from occupiers regarding the roof shading should be taken with caution and should be corroborated.

§ 17.27 Solar Heat Store Labelling

Solar heat store labelling should include:

- Rating of each internal heat exchanger and description of type.
- Maximum operating pressure of all primary heat exchangers.
- Stand-by heat loss rate, with allowance for variable solar temperatures.

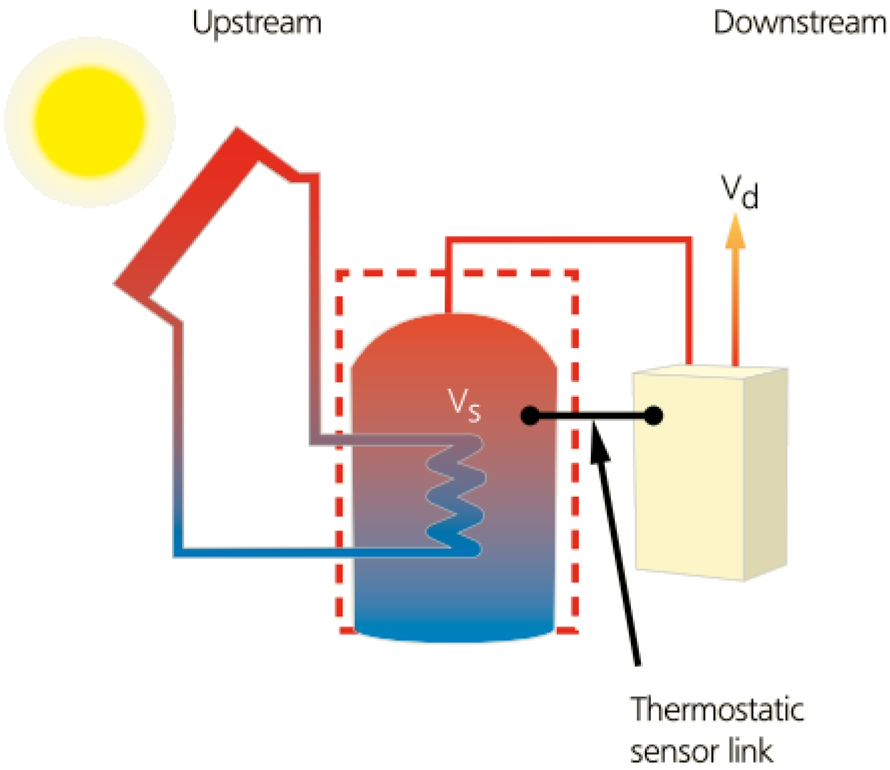
§ 17.28 System Types

§ 17.28.1 Fully-filled

- Air is displaced from the circuit by the transfer fluid present in the collector.
- Under normal conditions, the transfer fluid in the circuit would always be above atmospheric pressure.
- The system may be open to the atmosphere or sealed.
- The transfer fluid is normally an antifreeze solution to ensure continued functioning of safety devices in all conditions.
- Undesirable overnight heat loss is prevented by one-way check valves.

- Pipework can undulate provided air can be released at high points and fluid drained at low points.

- Fluid expansion is contained by an expansion vessel with an internal, flexible membrane.



§ 17.28.2 *Drainback*

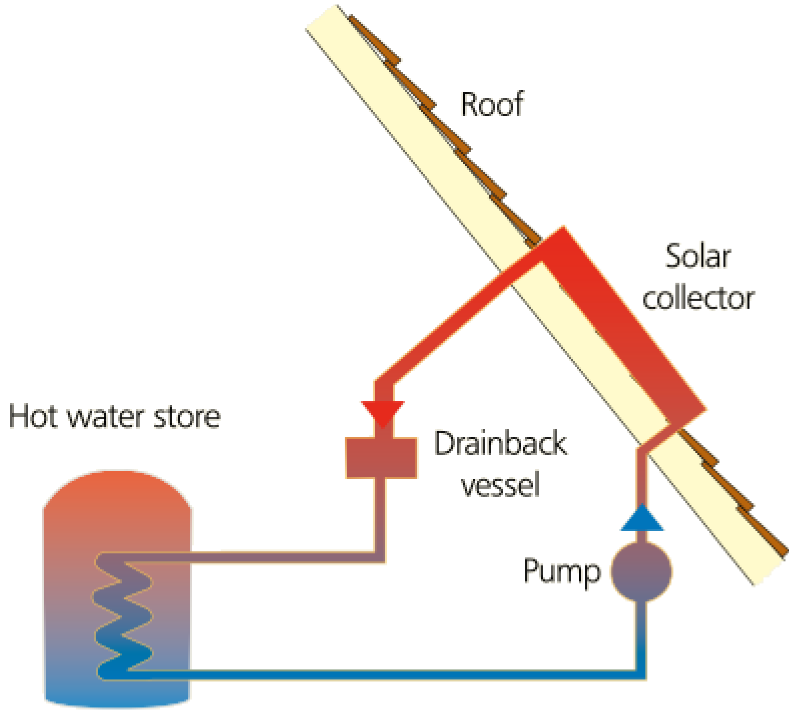
- A reservoir of air only allows the transfer liquid to reach the collector under the action of a pump.

- The transfer fluid may occasionally drop below atmospheric pressure.

- The system may be open to the atmosphere or sealed. The transfer fluid may be an antifreeze solution to ensure continued functioning of safety devices in all conditions.

- Undesirable thermosyphon circulation is prevented by switching the pump off: this allows drainback of liquid from the collector.

- Pipework must always fall towards the drainback vessel.
- Fluid expansion is contained by a vessel with an air pocket.



§ 17.28.3 Indirect System

A closed loop primary system (or indirect circuit) best meets these requirements. It allows heat to move from the collector into a pre-heat store by re-circulating the primary fluid. In normal operation, one pipe (the flow) takes hot fluid from the collector and the other (the return) will bring cooler fluid back. A heat exchanger is present in an indirect system to ensure that fresh cold water does not circulate into the primary solar collector loop.

§ 17.28.4 Direct System

A direct system does not have a heat exchanger; the transfer fluid is the same water that is ultimately used at the DHW taps and appliances. This type of circuit does permit fresh water to enter the collector loop with the risk of limescale deposition inside the absorber. Limescale reduces efficiency and in severe cases can block the primary loop. In freezing conditions there is a high risk that ice could form, blocking expansion and safety vents. Compliance with the water regulations can be onerous with respect to preventing damage to rigid components in unheated spaces.

§ 17.29 Temperature and Pressure

§ 17.29.1 Requirements

In the event of a circulation failure during hot weather, stagnation can occur causing maximum temperature and pressure. Primary fluid temperatures of over 150°C are commonplace in summer. Non-metallic (elastomeric) materials, fittings and accessories have a history of premature failure. Specialised components are normally required. The temperature and pressure limits of all components should be confirmed by permanent marking, identification or technical data left on site along with the full stagnation temperature. Non-metallic pipes carrying fluids on solar primary systems should be independently tested to ISO 9808 (BS 7431). In general, materials for solar primary circuits can be specified to ISO/TR 10217 and BS 6700. Other factors to consider are ultra-violet degradation and vermin.

§ 17.30 Testing, Initial

During the initial testing of a solar primary system, there is a high risk of scalding from stagnation heat built up in the absorber. When first filled, there can be an immediate steam flash and an intense heat shock to components.

During prolonged periods with no heat extraction, unwanted oxides can form on internal collector surfaces reducing heat transfer. Collectors should therefore remain covered until initial testing has been completed.

Unexpected leaks and emergency drain downs are best dealt with when the transfer fluid is cold. It is inevitable that unwanted particles and chemicals will get into components during pipe laying, so a primary system should first be flushed cold, then hot until clear.

However, great care must be taken to ensure that residual water is not unintentionally left in the system to dilute the antifreeze. Furthermore, if left for long periods, pockets of water could freeze (particularly in winter conditions) or corrode components such as pump rotors.

Once the system is shown to be leak-free and operational, a prolonged pressure test is recommended. Air is not a suitable test medium due to the danger of gaseous explosions and the inability to discern temperature fluctuations. In systems where antifreeze is to be used it should be added prior to the initial pressure test. This is because it reduces the surface tension properties of the water and therefore ‘searches out’ leaks that would otherwise not be identified during the test.

Solar pre-heat stores made from copper need to form an oxide layer on the interior surface to reduce corrosion risks. They should not, therefore, be left for long periods filled with unheated cold water. Briefly heating the store beyond 60ºC will permit this oxide layer to form.

Pipes should only be insulated after final pressure testing (except for pre-tested and continuous unbroken pipework runs used without joints or fittings). Guidance for pressure testing is given in BS 6700 (soon to be superseded by BS EN 806).

Putting all the pump control temperature sensors into a hot water bath before installation will allow a check on their accuracy. An accurate digital readout will allow imbalanced sensors to be discarded.

Collector temperature sensors can be susceptible to the absorption of unwanted moisture from prolonged temperature differentials and humidity. Special heat paste applied into sensor pockets reduces the chances of this.

§ 17.31 Testing, Periodic

During commissioning and periodic maintenance, it is necessary to check the circulation rate of the solar primary circuit fluid in order to confirm that sufficient heat extraction will occur under maximum irradiation. It is also necessary to check that unwanted air is removed from pipework prior to checking fluid levels. As these checks may take place when available solar irradiation does not create enough circulation (e.g. when cloudy or at night), a suitable method of providing circulation should be available at any time.

A solar primary system should include a manual override to engage circulation for commissioning in all weather conditions, plus a means of accurately indicating primary circulation rate. For the end-user and the commissioning engineer, it is important to pre-empt any potential loss of performance and to be able to monitor key system functions such as absorber and pre-heat water temperatures. This can be achieved using digital thermometers typically found with a DTC.

§ 17.32 Tools

Access

Current HSE recommendations require specialised access equipment, including eaves-level platforms, steel scaffold or towers, cranes or hoists.

Seed pumps

These are special high-flow pumps designed to rapidly fill solar primary systems and remove air or steam locks.

Hand pumps

For injecting extra antifreeze initially or during maintenance.

Refractrometers

For sampling antifreeze concentrations (alternatively use hydrometers).

pH testers (litmus paper)

These are usually coloured impregnated strips which can identify loss of corrosion protection.

High temperature brazing

This is used where soft solder joints are unsuitable at stagnation temperatures.

Covers

These are to stop irradiation reaching the absorber.

§ 17.33 Transfer Fluid

§ 17.33.1 Requirements

A transfer fluid moves heat from the collector into the dwelling. Because of the high stagnation temperatures and freezing temperatures in the winter, only specially prepared fluids should be used – and these may differ between systems. This fluid should not deposit limescale, sludge, ice or other solids that could restrict circulation or impair the rate of heat transfer. It normally contains anti-corrosion inhibitors and antifreeze. An accessible test point is required in the circuit to safely draw off small samples of transfer fluid for inspection during periodic maintenance. The antifreeze must be specifically designed for solar systems and present a low toxicity in the event of a leak. Typical car antifreeze must not be used. Provided annual inspections are carried out, the antifreeze may not need to be replaced in a well-designed system for the whole of its design life.

§ 17.33.2 Pumps

Thermosyphoning is the natural movement of fluid due to the difference in fluid buoyancy at different temperatures. Due to the layout of most UK dwellings, it is rare that thermosyphon circulation can be used instead of a pump. Safety factors, including the adequate control of heat circulation and conservation of stored heat, further restrict its application. The direct connection of a pump to a power source, such as a photovoltaic (PV) module, presents similar safety issues. In most cases, maximum efficiency and safety of circulation is achieved with a pump under temperature control.

§ 17.34 Water Quality

When incoming cold water is heated, it can produce limescale (due to water hardness). In some areas this may result in a build-up of a hard crust inside hot water stores causing a gradual decrease in the storage, circulation and heat exchange efficiency. Unwanted bacteria can grow in all cold and hot water systems, particularly under tepid temperature conditions with porous materials. The acidity, particularly of private water supplies in upland areas, can aggressively dissolve certain metals. Water quality must be assessed for each site before selecting secondary heating equipment.

New build: Water hardness can be ascertained from maps or from utility companies. Water quality reports based on postcodes are also available. Samples from private supplies will need to be analysed at a laboratory.

Existing: A site visit is required and this is best done by a suitably informed and trained person. The inspection will cover the cold water supply, secondary storage, distribution and appliances. Bacterial risk assessments are best recorded and summarised into low, medium and high risks according to the age of equipment, length of pipe runs, and the ability of auxiliary heat sources to achieve sterilisation at high flow rates.

§ 18 Appendix I: Android Quality Measures

Performance and Stability

Area	ID	Description	Tests	
Stability	PS-S1	App does not crash, force close, freeze, or otherwise function abnormally on any targeted device.	CR-all, SD-1, HA-1	X
Performance	PS-P1	App loads quickly or provides onscreen feedback to the user (a progress indicator or similar cue) if the app takes longer than two seconds to load.	CR-all, SD-1	X
	PS-P2	With StrictMode enabled (see StrictMode Testing, below), no red flashes (performance warnings from StrictMode) are visible when exercising the app, including during game play, animations and UI transitions, and any other part of the app.	PM-1	X
Media	PS-M1	Music and video playback is smooth, without crackle, stutter, or other artifacts, during normal app usage and load.	CR-all, SD-1, HA-1	X
Visual quality	PS-V1	App displays graphics, text, images, and other UI elements without noticeable distortion, blurring, or pixelation. App provides high-quality graphics for all targeted screen sizes and form factors, including for larger-screen devices such as tablets. No aliasing at the edges of menus, buttons, and other UI elements is visible.	CR-all	X
	PS-V2	App displays text and text blocks in an acceptable manner. Composition is acceptable in all supported form factors, including for larger-screen devices such as tablets. No cut-off letters or words are visible. No improper word wraps within buttons or icons are visible. Sufficient spacing between text and surrounding elements.		X

Google Play

Area	ID	Description	Tests	
Policies	GP-P1	App strictly adheres to the terms of the Google Play Developer Content Policyand does not offer inappropriate content, does not use intellectual property or brand of others, and so on.	GP-all	?
	GP-P2	App maturity level is set appropriately, based on the Content Rating Guidelines. Especially, note that apps that request permission to use the device location cannot be given the maturity level "Everyone".	GP-1	X
App Details Page	GP-D1	App feature graphic follows the guidelines outlined in this blog post. Make sure that: The app listing includes a high-quality feature graphic. The feature graphic does not contain device images, screenshots, or small text that will be illegible when scaled down and displayed on the smallest screen size that your app is targeting. The feature graphic does not resemble an advertisement.	GP-1, GP-2	?
	GP-D2	App screenshots and videos do not show or reference non-Android devices.	GP-1	?
	GP-D3	App screenshots or videos do not represent the content and experience of your app in a misleading way.		?
User Support	GP-X1	Common user-reported bugs in the Reviews tab of the Google Play page are addressed if they are reproducible and occur on many different devices. If a bug occurs on only a few devices, you should still address it if those devices are particularly popular or new.	GP-1	X

Visual Design and User Interaction

Area	ID	Description	Tests	Pass
Standard design	UX-B1	App follows Android Design guidelines and uses common UI patterns and icons: App does not redefine the expected function of a system icon (such as the Back button). App does not replace a system icon with a completely different icon if it triggers the standard UI behavior. If the app provides a customized version of a standard system icon, the icon strongly resembles the system icon and triggers the standard system behavior. App does not redefine or misuse Android UI patterns, such that icons or behaviors could be misleading or confusing to users.	CR-all	X
Navigation	UX-N1	App supports standard system Back button navigation and does not make use of any custom, on-screen "Back button" prompts.	CR-3	X
	UX-N2	All dialogs are dismissable using the Back button.	CR-3	X
	UX-N3	Pressing the Home button at any point navigates to the Home screen of the device.	CR-1	X
Notifications	UX-S1	Notifications follow Android Design guidelines. In particular: Multiple notifications are stacked into a single notification object, where possible. Notifications are persistent only if related to ongoing events (such as music playback or a phone call). Notifications do not contain advertising or content unrelated to the core function of the app, unless the user has opted in.	CR-11	X
	UX-S2	App uses notifications only to: Indicate a change in context relating to the user personally (such as an incoming message), or Expose information/controls relating to an ongoing event (such as music playback or a phone call).	CR-11	X

Functionality

Area	ID	Description	Tests	
Permissions	FN-P1	App requests only the absolute minimum permissions that it needs to support core functionality.	CR-11	X
	FN-P2	App does not request permissions to access sensitive data (such as Contacts or the System Log) or services that can cost the user money (such as the Dialer or SMS), unless related to a core capability of the app.		X
Install location	FN-L1	App functions normally when installed on SD card (if supported by app). Supporting installation to SD card is recommended for most large apps (10MB+). See the App Install Location developer guide for information about which types of apps should support installation to SD card.	SD-1	X
Audio	FN-A1	Audio does not play when the screen is off, unless this is a core feature (for example, the app is a music player).	CR-7	X
	FN-A2	Audio does not play behind the lock screen, unless this is a core feature.	CR-8	X
	FN-A3	Audio does not play on the home screen or over another app, unless this is a core feature.	CR-1,CR-2	X
	FN-A4	Audio resumes when the app returns to the foreground, or indicates to the user that playback is in a paused state.	CR-1, CR-8	X
UI and Graphics	FN-U1	App supports both landscape and portrait orientations (if possible). Orientations expose largely the same features and actions and preserve functional parity. Minor changes in content or views are acceptable.	CR-5	?
	FN-U2	App uses the whole screen in both orientations and does not letterbox to account for orientation changes. Minor letterboxing to compensate for small variations in screen geometry is acceptable.	CR-5	?
	FN-U3	App correctly handles rapid transitions between display orientations without rendering problems.	CR-5	?
User/app state	FN-S1	App should not leave any services running when the app is in the background, unless related to a core capability of the app. For example, the app should not leave services running to maintain a network connection for notifications, to maintain a Bluetooth connection, or to keep the GPS powered-on.	CR-6	X
	FN-S2	App correctly preserves and restores user or app state. App preserves user or app state when leaving the foreground and prevents accidental data loss due to back-navigation and other state changes. When returning to the foreground, the app must restore the preserved state and any significant stateful transaction that was pending, such as changes to editable fields, game progress, menus, videos, and other sections of the app or game. When the app is resumed from the Recents app switcher, the app returns the user to the exact state in which it was last used. When the app is resumed after the device wakes from sleep (locked) state, the app returns the user to the exact state in which it was last used. When the app is relaunched from Home or All Apps, the app restores the app state as closely as possible to the previous state. On Back keypresses, the app gives the user the option of saving any app or user state that would otherwise be lost on back-navigation.	CR-1, CR-3, CR-5	X

§ 19 Appendix J: Helios

Attached to this report is a CD containing the following:

- The entire source code and resources for Helios
- The .apk file that can be installed to any Android phone or tablet
- Video of Helios in action

Java files are in `Helios\app\src\main\java\com\example\mk\helios`

Layout and resource files are in `Helios\app\src\main\res`

It is highly recommended that the entire project is opened in Android Studio to read any code.

This data is also available at the following web address, just in case the CD is not accessible.

https://mklimuszka.wordpress.com/helios/

How to install Helios:

1. Go to Settings > Security. Check "Allow installation of apps from unknown sources."
2. Move Helios.apk to the device through any means (email, download, USB, etc.)
3. Locate the Helios.apk file and run it.