WESTERN POWER DISTRIBUTION

INNOVATION

NEXT GENERATION NETWORKS

# CARBON TRACING

# CLOSEDOWN REPORT

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# Contents

## Executive Summary

The Carbon Tracer project successfully delivered an App and shadow website which enables customers (or other interested parties) to choose any location in the WPD remit area and find out the instantaneous energy mix, and therefore the carbon intensity for their selected location. This is provided as a 7 day **History** or **Forecast,** and in a **Now** and more detailed **Today** mode.

The main challenges for the project were the sourcing of the data required to "power" the app and the creation of a design for the deployment of the app functionality which was simple yet engaging. We worked with internal projects which had prepared data under the umbrella of the strategic studies programme to address the former, and for the latter we used consultancy from Carbon Trust to investigate ergonomics for the app and to prepare a view of the sort of GUI that was required. Enigma Interactive have experience in app production and as well as app implementation, test and rollout, and were also able to add to the planned design at an early stage.

Take up of the app was very encouraging from the start, assisted by planned marketing activities by both WPD and Carbon Trust using social media, press releases, internal publications, standard search engine and app store "tags". The usage analytics are being studied on an ongoing basis to obtain information on how customers interact with such apps and the extent to which they are prepared to modify their behaviour as a result, including their willingness to shift energy usage on the basis of carbon intensity projections (effectively DSR under NIA rules).

At the time of preparation of this report, over 2200 distinct downloads/users had been seen and customer feedback showed that it has been well received. The project found that up to 15% of users of the app can be expected to consult the application and are prepared take deferment action for discretionary energy use. In terms of the educational value of the app, we also found that in all of the main categories that were put to the users, the proportion of responses indicating awareness of the attendant issues was raised by between 10 to 20 points. Given these positive outcomes and the likelihood that automation will result in even better take-up for Demand Side Response (DSR) actions, this clearly points to there being sufficient potential to deliver further value through the Carbon Portal follow-on project.

The development project described in this document proceeded to budget and plan, and the deployed app and website are continuing in use following implementation project closedown.

# 1 Project Background

## 1.1 Previous and Related Projects

Prior to the project implementation phase commencing, WPD Future Networks had developed an update to the WPD public facing website to add the capability to see a generation capacity map. The map website used mapping capabilities to display (at the primary substation level), available values for parameters such as reverse power flow, load and attached generation with a RAG status where this was helpful to visualise the data. The data from this earlier project (specifically the WPD-GEN-INFO.TXT overnight file) and elements of the approach were able to be used to design the new Carbon Tracer App and supporting website.

Significant assistance was made available to the project by the WPD Strategic Studies Programme. This provided geographical polygons for so called Electricity Supply Areas and the additional data needed to classify and assign template load profiles to all BSPs in the four WPD operating regions. This gave the project a ready means by which to locate a user on the WPD distribution network and also to define the load/demand at each BSP using the normalised template curves scaled to an actual value using the maximum demand value for each.

## 1.2 Statement of Problem

Prior to the project there was no mechanism available for informing customers about the make-up of generation in their area. Providing a mechanism for customers to find out this detail via their mobile phones, tablets or internet would therefore potentially act as:

- A catalyst for providing more information about generation and raising awareness about this and WPD/DNOs in general;
- A potential new avenue into the community and those customers with an interest in finding out where the energy they use comes from.

It was also considered that the project outcomes would potentially assist with the development of future apps, in particular the planning of future engagement for Demand Side Management, allowing customers to see the impact of their actions and possibly adjust their usage to other times. The Carbon Tracer functionality would lend itself to operating other additional customer DSM apps.

## 1.3 Method

The project had an early research phase during which time the base functionality was laid out, and initial research and guiding input was gathered by engaging the Carbon Trust (identified as CT below) as a project partner. A framework for the user interface was derived, with a key message being simplicity and clarity. This interval also presented actual screen layout suggestions and proposed the RAG (Red/Amber/Green traffic light) type approach to signalling actions to the App users. At this point there was a pause in the schedule to realign the project to a new plan with a slightly increased budget.

A second project phase then developed the outline design, capturing this in a formal Requirements Specification which was then issued to the identified developer, Enigma Interactive, who had worked on the associated project to deliver the Generation Capacity web map. The data requirements were identified and documented once the calculation algorithms were determined and both were added to the developer maintained Functional Specification for the system. Development, implementation and test followed in house with the developer and finally the system was deployed to the host.

## 1.4 Approach

The project followed a reasonably standard agile IT project lifecycle consisting of these principal activities carried out by the indicated parties:

- Desk based research and environmental psychology investigative work (CT);
- Marketing analysis (CT)
- Requirements definition (WPD);
- Outline Design (WPD);
- Top level Design and data specification (WPD);
- IT methodology analysis and Functional Specification (WPD/Enigma);
- Outline screen designs creation (wire frames) (Enigma);
- User Interface wire-frames preparation (Enigma);
- Base functionality implementation (Enigma);
- Data gathering and master data set production (WPD);
- User test of Wire Frames and user feedback report (CT);
- Enhanced functionality added based on user feedback (Enigma);
- Minor functional additions (one CR produced to cover) (Enigma);
- Integration test (Enigma);
- Host sizing exercise (Enigma);
- Validation test (WPD/Enigma);
- Pre-release tests (WPD/Enigma);
- Go-live (WPD/Enigma);
- User Feedback analysis (CT);
- Support (Enigma).

# 2 Scope & Objectives

The project was principally concerned with the preparation, production and rollout of a new App and website to allow customers to self-serve Carbon Tracing information. The secondary objective was the gathering of feedback from users and analysis of their perceptions and behaviour to see whether they engaged with the ability of the app to redirect their energy usage activities through DSM (deferment to greener times). There is additional value add in respect of app design, capabilities and also from the data investigation all of which can be re-used to inform future development projects.

| Objective | Status |
|---|---|
| Identification, gathering and presentation of data required to support the app and website | ✓ |
| Design, production, rollout and support of a Carbon Tracing App and supporting Website | ✓ |
| Use of App by customers | ✓ |
| Gathering of usage stats and view of user behaviours | ✓ |

# 3 Success Criteria

The Project includes the following main identifiable steps which can be assessed for completeness and an indication of successful conclusion:

| Project Objective | Measure of Success |
| --- | --- |
| Identification, gathering and presentation of data required to support the app and website | ✓ Availability of data |
| Design, production, rollout and support of a Carbon Tracing App and supporting Website | ✓ Creation and live availability of both (the app in variants for Apply and Android). |
| Use of App by customers. | ✓ Downloads, accesses, user feedback and analytics |
| Gathering of usage stats and view of user behaviours | ✓ Information available allowing conclusions to be drawn |

Separate objectives were identified for the app during the design and development phase. These were listed to serve as KPIs to measure the success of the app design.

| App Objective | Measure of Success |
| --- | --- |
| Provide WPD with understanding of what extent their customers are engaged by the concept of carbon intensity. | Positive user feedback on how much the information in the app engages the user |
| | Analysis of app data to test sustained use of app |
| | Number of app downloads and website users |
| To help people have an improved understanding of their local energy supply | Evidence that awareness on issues related to the user's local electricity system has improved as a result of using the app |
| To understand whether the app, in its original form or through a future iteration, could elicit behaviour change | Positive user feedback on how much they have / are willing to change their behaviour using the app |
| | Indirect feedback through use of Reward feature to see how often people were willing to move their energy use to 'greener' times |

# 4 Details of the Work Carried Out

The project was conducted broadly as planned and had two main phases, firstly to prepare the overall approach and then in a second phase to implement and rollout the systems. The main phases are listed in the "Approach" section above. Some restructuring was necessary in order to ensure that the project met the main objectives of delivering the app/website and also getting the user and behavioural feedback. The involvement of Carbon Trust was initiated to ensure user engagement was as complete as possible, but also to provide design (usage/look and feel) input.

The project deployed a customer App for mobile phone with a shadow website in February 2018. This App was used to compute instantaneous values at each BSP for demand and local generation (by type), taking into account a number of factors which control both. BMRS data from Elexon was used to define the breakdown of any infeed completing the picture, giving all the components of the supply to any customer connected to the BSP. The result was an instantaneous view of carbon intensity which the users could act upon if they wished. Data was key to this whole process and had to be prepared by a largely bespoke means which would need repeating, or a similar path following, for future app developments. Learning from this area was gathered during the project to aid in the preparation of a possible future support and enhancement phase.

## 4.1 Background Research and Feature Analysis

The Carbon Trust conducted research in two phases. Initially the research focused on academia in the fields of environmental psychology and public engagement in domestic energy usage. This also included looking at examples of similar software, and speaking to the developers to capture their learnings. After this background research was completed, Carbon Trust then proceeded to conduct interviews with academics, project leaders or app designers involved in projects most related to the Carbon Tracer app. The Carbon Trust held internal and external workshops with stakeholders and experts to gain further insights into what a successful app would contain.

Research found that there are a number of apps in the market that attempt to engage consumers and customers with their energy use and the provenance of the energy they use (e.g. GridCarbon, Sandbag, Ecotricity's 'UK Grid LIVE'). These apps help communicate carbon intensity at a national level and they have varying levels of penetration in the UK. Analysis was undertaken to assess what features these apps had and how the Carbon Tracer App could fill a gap in the market but also implement or improve on features from these similar apps.

The analysis of these similar projects in combination with learnings from the scientific literature yielded significant information about the way customers engage with their energy use and wider usage habits that would have an influence on the iteration of a successful app.

The key points summarised from interviews with experts and the literature review for the design and development phase of the Carbon Tracer app were:

1. Research in the field of environmental psychology and eco-feedback technology design suggests a highly nuanced approach is required to engage different consumer segments on topics such as energy use and carbon emissions. There is no one silver bullet to engage all users and motivating individuals to change their energy usage behaviour is challenging. Previous apps in the UK on the topic of carbon intensity of electricity have not focused on exploring different methods of engagement and rather catered to a highly technical and knowledgeable segment of consumers.

2. Numbers and metrics are only interesting for consumers with a good understanding of the energy system and may not appeal or engage the average consumer. Evidence suggests that metrics often discourage users who do not have technical backgrounds.

3. Visualisation of data is an important way of making inaccessible numbers more engaging. This can be done using techniques like the traffic light system used by Ecotricity developed by Damon Hart-Davis. A colour-coded forecast, such as that used by Enrico Costanza, could also be effective.

4. Just showing information has only a marginal effect in driving pro-environment behaviour. Motivating engagement, both initial and long-term, is dependent on that information being actionable and relevant to the user. Therefore the functionalities the app offers is very important.
    a. Functionalities allowing comparisons across individuals or groups could potentially drive engagement.
    b. An advanced view with option to download data and carry out user-constructed plots would appeal to the more technical users.
    c. Information that is provided along with advice on, or opportunity for, behaviour change is powerful way of creating engagement.

5. The app should be careful to balance presenting too much information and putting off consumers and giving too little context that consumers could misinterpret the

data. A common issue identified through end-user interviews was the misunderstanding between tariff claims and real physical power flows. This led to some users not understanding why the app would tell them that the renewable content of their electricity supply would vary during the day, even though they were on a 100% renewable tariff.

6. Maintaining communication with the user is vital. This can be done through regular emails containing feedback, or using an alert system to notify users of certain events. However, too many emails or messages may put-off users, and result in them being ignored.

7. Knowing the target audience is key to choosing the most cost-effective method of recruitment for a trial of the app. Traditional methods (e.g. door-knocking, letters, phone-calls) may now be overly expensive, slow, and most importantly ineffective compared to cheaper, more focussed digital advertising.

Internal and external workshops were held which validated these findings and aided in the ideation phase, i.e. the formation of early concepts of features the app should contain. These included early versions of the Now, Today and Forecast screens (features included in the version of the app that was released to the public), as well as methods of providing information on how people could change their behaviour by using different appliances at different times of the day.

## 4.2 Requirements Gathering

As part of the project, a requirements specification was produced in order to formalise these at the project outset. The broad functions that were required of the app and website were identified and a number of secondary "desirable" requirements were also listed in order to add breadth to the app. It was always intended that these secondary requirements would be "tradeable" and not be formalised as development subcontractor deliverables. This approach would allow flexibility through the development without constant course to agreements thereby allowing an agile approach to be adopted. The spec is in Ref [2].

## 4.3 Requirements Analysis

This task followed on immediately from the user requirements gathering activity and involved collating the results and allocating priorities to individual entries with a view to scoping the supply from the chosen developers.

## 4.4 Scoping, Agreements and Team Formation

The initial project phase included the identification of Carbon Trust as the main project partner to add the weight of their reputation, experience and extended lists of contacts in the area of Carbon footprints to the project overall. This resulted in some early key user side information and user interface layouts for guiding the later design of the app. The BMRS had also been identified in this phase as the source of the national level information on the make-up of the energy supply.

In April 2017 the Project Manager changed and the design phase proper commenced. A change had been in preparation to increase the budget and add significantly to the marketing area. However the new PM and FNT Management were in agreement that the proposed budget placed the emphasis in the wrong place and that much more focus should be placed on the app design and also on sourcing the data required to support the system from within the business. This was done through April and May and the developers were then chosen. At the time Enigma Interactive had just finished a number of web based developments for WPD (Generation Capacity Web Map) and were in negotiation with WPD Digital Communications Department about further work. Enigma were invited to provide their pricing and confirm the availability of resources that would be able to deliver the required systems by the end of the year.

With a new budget allocation, the scope was agreed with Carbon Trust and Enigma and both were engaged on the project with the support of WPD Procurement.

## 4.5 Design, Development & Test

### Design

The app design had not been fully captured by the start of phase 2 (at the time of the change of Project Manager). This was therefore an early priority in this phase. It was therefore necessary to establish how to service the customer requests and locate the data necessary to achieve this from within the organisation, equating the functionality identified by the Carbon Trust with the data that was available so as to identify what was reasonably possible.

The first decision was to decide at what level to support the queries. This was informed by some work recently completed by the new PM on an update to the WPD public facing website area: *Generation Capacity Map*. The Generation Capacity Map is a website only tool implemented at the Primary Substation Level and it had been determined during this work that there were some 1800 WPD primaries for which data was therefore required. The data management task for this had been eased by the availability of Long Term Development Strategy (LTDS) reporting data on firm capacity, maximum load and fault levels but there had still been considerable effort required to populate, sanitise and check this for use on the website and to merge the generation information obtained from the CROWN EAM system (and directed to the WPD-GEN-INFO.TXT so called "overnight file" uploaded from WPD to Solsoft, the web hosts for this area). The Generation capacity map functions were designed to support connection enquiries prior to initiation of formal connection requests for generators so the primary level was appropriate in this case.

For the Carbon Tracing functionality however, the level of work required to obtain the data for the system and manage this at primary level appeared daunting and at the same time GSP level would have given too coarse an analysis. Using the BSP as the substation level at which the user would be localised to the WPD network therefore emerged from the analysis as the obvious choice. Initial checks of the data gathered for the Generation Capacity Map showed that there were some 270 BSPs across the four WPD DNO regions which would be required, and this seemed entirely manageable (see next section).

Having determined the analysis would be done for each BSP, the high level design steps could be isolated as:

- User interface aspects;
- Localisation of user to the WPD network (specifically to a BSP);
- Determination of load at the time of the request;
- Determination of the local time at the BSP location for the purposes of computation of solar output from PV installations. The actual true local time differs from civil time because of the longitude of the BSP (E/W of Greenwich) and an effect called the Equation of Time. The former is a fixed value, the latter varies throughout the year (see Figure 14);
- Determination of the amount of local generation at the time of the request and given the current prevailing weather conditions;
- Determination of the difference between local Generation and instantaneous load, this amount to be imported from the National Grid;
- Given the mix, taken from local generation available and Grid infeed from the BMRS, the UK Department for Business, Energy and Industrial Strategy Fuel Mix Disclosure Table can then be used to compute the total Carbon Intensity from these $gCO_2/kWh$ figures.

An overview schematic of the App design is shown below:

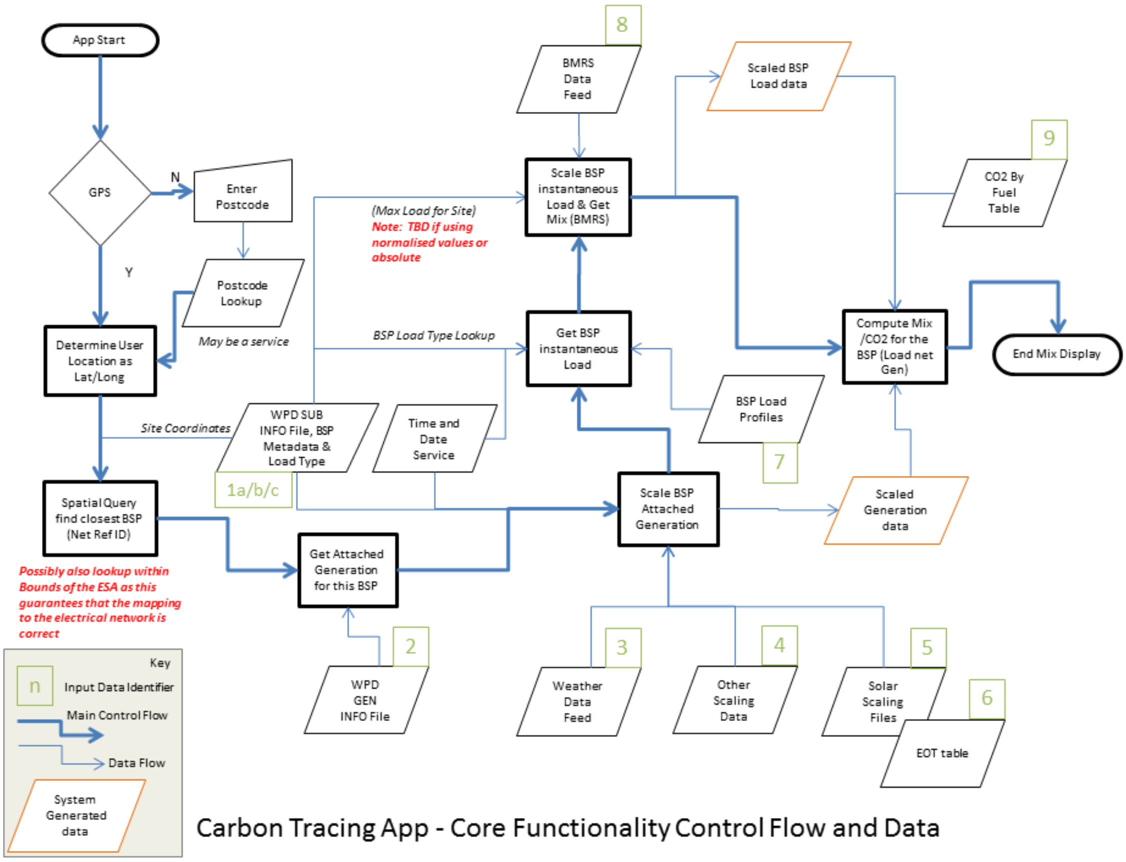



**Figure 1 - App Main Control Flow**

## Localisation of User to WPD Network

The app would be driven by a map based interface (Google Maps) which would be the main functional point of entry for users (immediately following introductory information pages which can be skipped thereafter, once seen). The user would be able to select any location inside the four WPD DNO regions using the following means:

- Postcode;
- Click on map;
- Call up previously used location from stored list;
- Use current GPS coordinates (enabled mobile devices).

To service this accurately, and pin the user to the correct BSP supplying the selected location, it would therefore be necessary to know the geographical extent of the feeders for all BSPs. It happened that this analysis had previously been carried out on another project by a company called (at the time) RegenSW (now just Regen). Regen have defined a set of polygons at different levels (GSP, BSP and most recently Primary) which define so called Electricity Supply Areas (ESA's). These polygons are available as geographic overlays for tools such as Google Earth, and may also be imported into GIS management systems against which a query can then determine the specific polygon from the set of all polygons inside which a users' selected coordinates lie. This capability (at different levels) is a key capability which can be generalised and used to support any number of future WPD apps.

The full polygon set is shown (imported into Google earth for convenience) below in Figure 2 and an expanded detail for the SW is in Figure 3. There are around 270 polygons/BSPs. The metadata for each polygon contains the Network Reference ID for the associated BSP and this then provides the necessary hook for looking up the BSP data needed to carry out the analysis for the app.

The BSP polygon definitions were therefore obtained for the project along with a BSP metadata file managed by another PSD project.

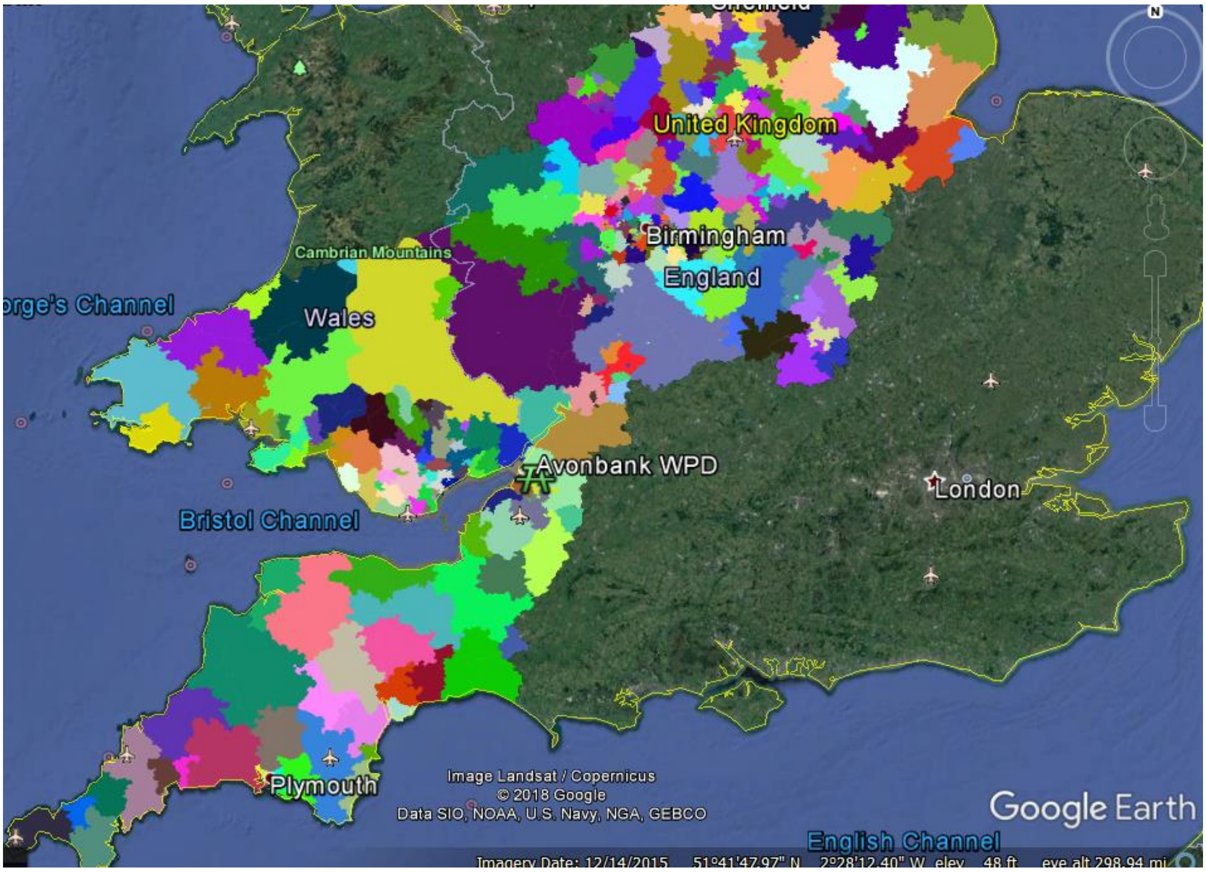



Figure 2 - Full Set of WPD Supply Area Polygons at the BSP Level

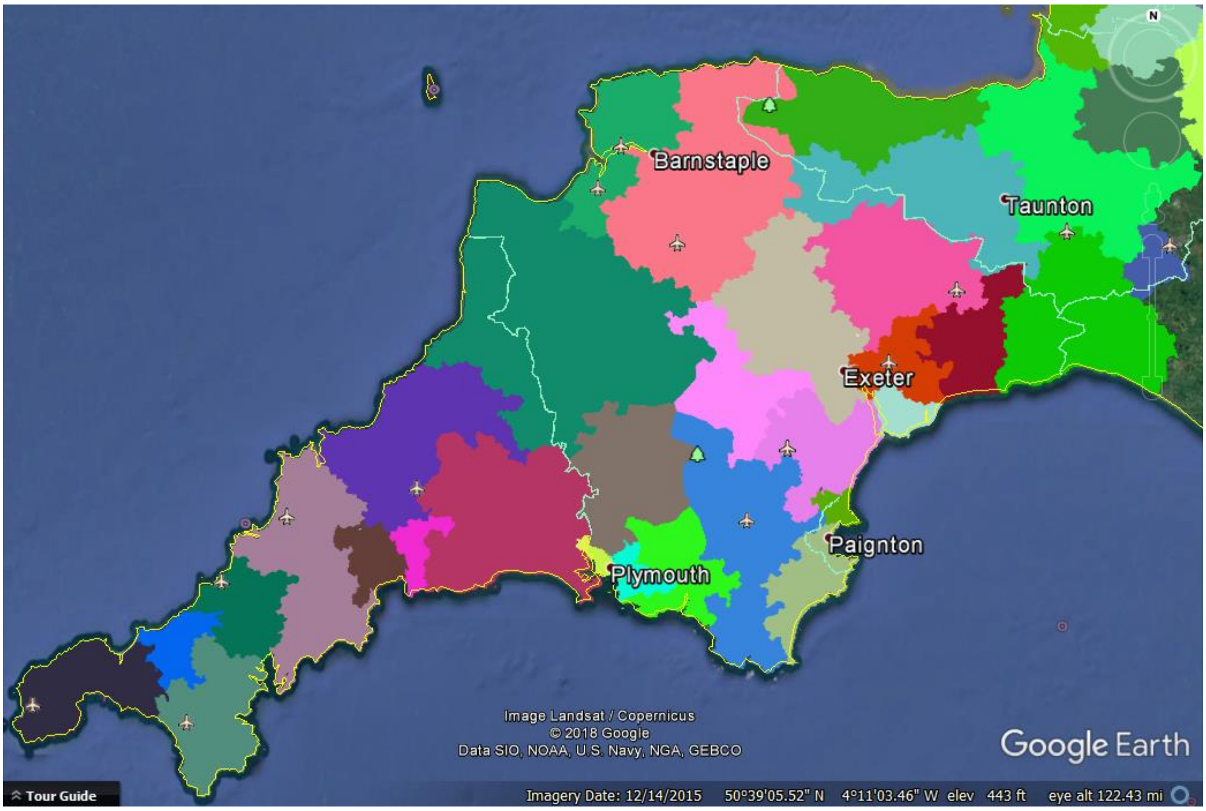



Figure 3 - Polygon Area Detail - South West

The list of BSP Network Reference IDs inside each of the polygons was obtained from the GIS fileset (DBF file) and cross checked to the BSP metadata file. The matching IDs were selected as the set of BSPs for use by the app and the data for these was then developed. BSP metadata file list entries not represented by a supply area polygon needed to be understood, and after referring to the PSD project it became apparent that these were individual (industrial) customer supplies.

## Main Algorithm

The basis of the electricity supply mix calculation is shown below in Figure 4. Essentially the app assumes that local generation attached under the BSP is consumed first locally and any demand shortfall is filled by infeed from the National Grid. To determine the instantaneous carbon intensity at the users location requires the app to know two things:

- The make-up of the electricity being used to meet current demand, i.e. the composition of the electricity being consumed by fuel type;
- The carbon intensity of each fuel type (this is available from the official figures in Ref 5).

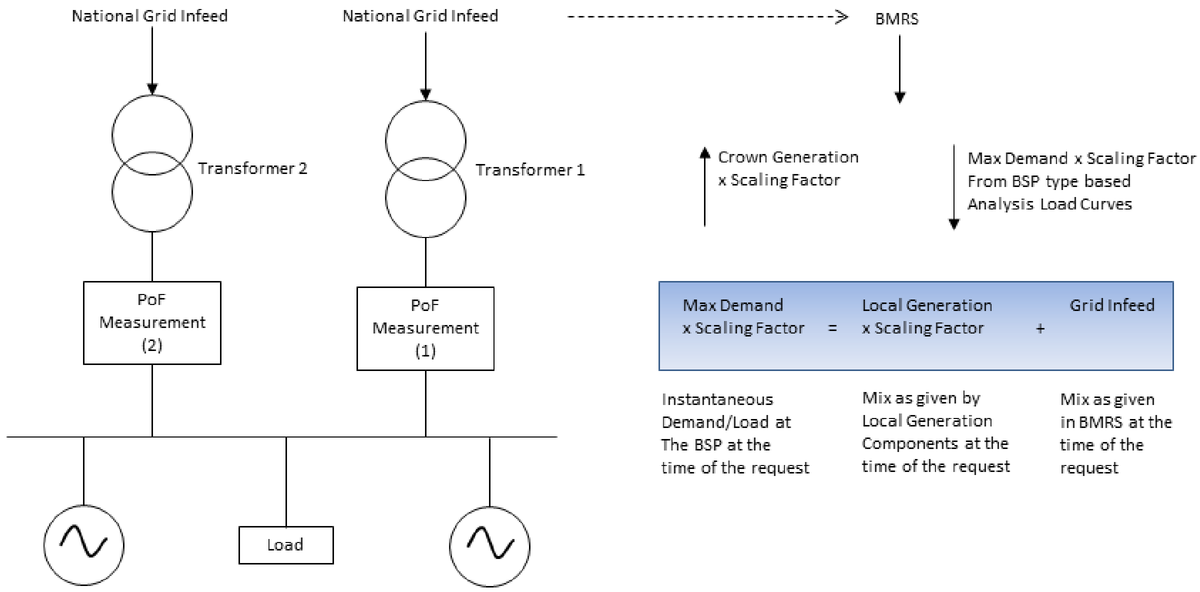



Figure 4 - Main Mix Determination Algorithm

To compute the locally attached generation contribution, the attached capacity by generator type records from CROWN are used. These list the generators using the following classes (the table also lists the totals across all BSPs at July 2017 with these values displayed in the chart in Figure 9):

| Generation Type | Total MW |
|---|---|
| Photovoltaic | 3583.01 |
| Other Generation | 1580.74 |
| Onshore Wind | 955.24 |
| Mixed | 484.76 |
| Landfill Gas, Sewage Gas, Biogas (not CHP) | 386.84 |
| Biomass & Energy Crops (not CHP) | 126.25 |
| Waste Incineration (not CHP) | 102.84 |
| Large CHP (>=50mw) | 74.00 |
| Medium CHP (>5MW,<50MW) | 61.25 |
| Small CHP (>1MW, <5MW) | 49.65 |
| Storage (Battery) | 36.09 |
| Mini CHP (<1MW) | 21.54 |
| Hydro | 17.89 |
| Micro CHP (Domestic) | 0.28 |
| Tidal Stream & Wave Power | 0.05 |
| Offshore Wind | 0.00 |

Table 1 - Total Generation by Type (All WPD)

The generator capacity information is available in a file called WPD-GEN-INFO.TXT that was already being passed externally to Solsoft and which could be used without revision to support the Carbon Tracer App. The entries in the file are indexed using the Network Reference ID which again forms the basis of the look-ups to ensure that the data is associated with the correct BSP.

The generators are not supplying at declared capacity however, and it is necessary to scale the different generators declared capacity according to prevailing conditions in order to obtain a best estimate for the generation coming from each type at any given time, with different factors affecting the different generation methods. For instance:

- Solar farms do not operate at all at night. They only generate their maximum theoretical output at local noon on sunny days in the height of the summer. At other seasons, times, and when the sky is cloudy or the atmosphere opaque, the output of a solar installation is scaled back from the maximum possible output. They may also be unavailable at intervals due to maintenance or fault but in most respects the solar output can be modelled very accurately given appropriate input information (weather feed, time and date information, theoretical response curves);
- Wind farms only operate efficiently when there is air flow sufficient to move the turbine blades, and the generation output level is dependent on the amount of wind which clearly varies over time as the weather changes;
- Incinerators (of whatever material – biomass, waste etc.) have individual operational cycles which include outage periods for planned maintenance and/or unplanned faults. They also use a wide range of different fuels, some of which may be considered renewable, while others may not.

Collecting together all of the generation attached to the BSP or the primaries under it then yields a total maximum generation which can then be scaled to an actual final total value according to the season, time of day and weather conditions and offset against the grid infeed whose mix is given by the BMRS data feed. The result is the actual best view of the generation mix for that BSP and hence the customers attached to the WPD network under that BSP. This can then be displayed to the customer/user by the app either as a split by generation type (as a percentage of the overall total and/or in engineering units of MW at the BSP level) OR in terms of the carbon intensity of the elements of the mix. A further breakdown of the mix could also then be given showing the split renewables VS non-renewables. The form of the display to the user may be selected according to the customer's preferences.

## Scaling of Generation

The instantaneous value for wind generation (onshore/offshore) is affected principally by the speed of the wind, and so the current wind generation value needs to be scaled back from the maximum achievable capacity using this measure. To do this in the app we use values taken from a weather feed for a weather station close to the BSP to which the wind generation is connected. The efficiency of the generator turbines can then be determined using the prevailing wind speed and a calibration curve which converts this to an efficiency factor.

All wind generation is collected together under a single grouping for this purpose, and the figure computed for all attached units using a single mapping curve. Such wind "calibration" curves are dependent on the size of the turbines and without access to a reference list of turbine types by location, the only viable approach, in this version of the app, is to use a single generalised curve such as that shown below for a 300kW (typical) size.

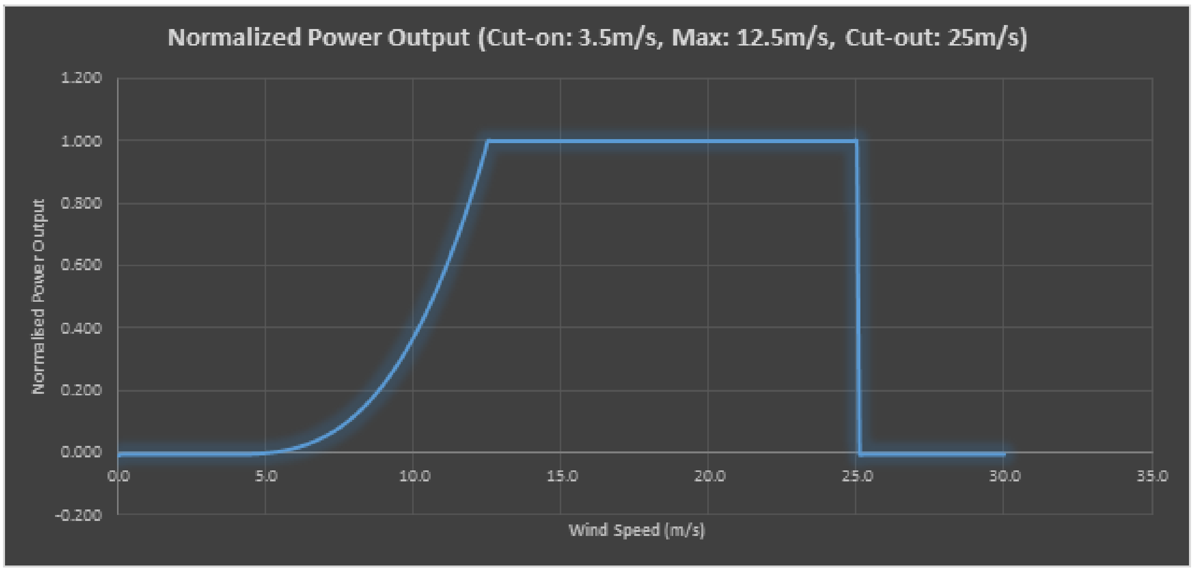



Figure 5 - Wind Generation, Calibration Curve (300kW Turbine)

The Power Output is related to wind-speed via a cubic relationship: $P = \frac{1}{2} C_P \rho A U^3$ where P is the power output and U is the wind-speed. All other terms are constants. Each turbine is different and even the normalised power output depends on the height of the turbine as well as the rotor length.

The output ramps up to a maximum from low values of wind speed where output is close to zero. Here the flow of air is insufficient to move the turbine blades to generate power. Once workable wind speed is reached there is a usable range at maximum output until this drops abruptly to zero at a cut-off point. This cut-out is necessary to ensure that high winds do not damage the turbines.

The approach is different for solar generation where the process of solar scaling carried out by the Carbon Tracing app requires these steps:

1. The maximum capacity is registered with WPD by the generation operator. This initial theoretical maximum is in fact never achieved and is first scaled back to around 98% of its theoretical max value even under ideal conditions;
2. Scaling using the daily response curve to adjust the effective PV output using time of day and day within the year to select the instantaneous value to use. The scaling is applied to the 98% value from step (1);
3. Further adjustment of the scaled value output from steps (1 & 2) using the cloud cover amount as reported by a weather data feed including this data;
4. Scaling for ambient temperature is not currently carried out.

For solar generation there are a number of factors in play which act to adjust the efficiency of the PV arrays. Firstly there is a daily response curve which is shaped like a bell and is centred on the LOCAL solar noon (the time when the sun is its highest in the sky to the immediate south of the customer). The shape of the bell also changes through the year being wide and tall in summer, tall and of medium width in spring and autumn and small and narrow in winter when there are fewer daylight hours and the sun is not high in the sky. This response which is theoretically at its maximum at local noon around the summer solstice is further affected by the weather with cloud cover acting to reduce the output of the arrays. These two main factors may be included in the design of the app by incorporating the daily response curves and using a weather feed. A Solar response heatmap (red high, blue low values) for the response curve generated for the Bras model for typical WPD locations is shown below, day in year left to right, time of day top to bottom. It is readily seen that the plot is thicker in the middle (summer) where there are more hours of usable daylight required for PV systems to operate efficiently.

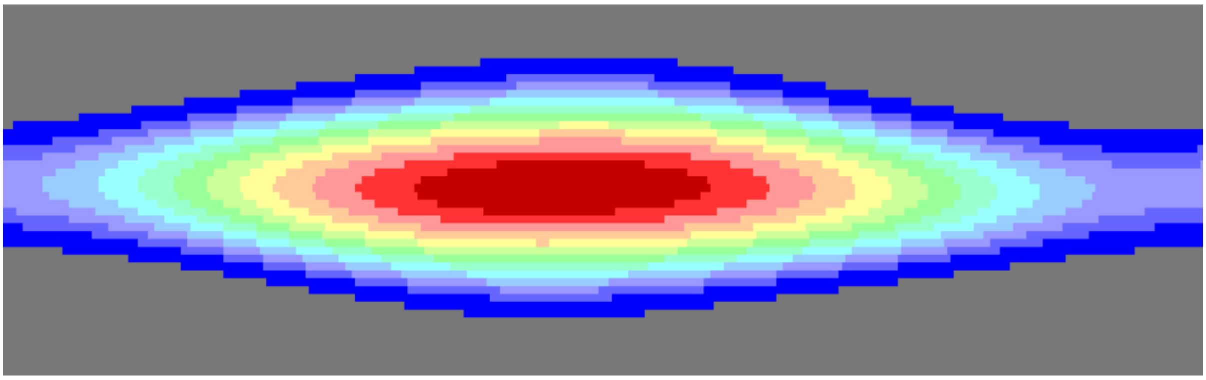


Figure 6 - Solar Response Heat Map

A single day response curve (bell curve) is reproduced below and corresponds to a vertical slice through the middle of the above annual heatmap. The plot is an output from a modelling tool which implements the Bras scientific model of solar irradiance over 48 half hour data points, normalised to a value of 1 at the annual peak. The example given below is for 20th June, being the time of maximum response. The peak is at the mid-point of the curve, and occurs at local noon. The model has been used to generate reference curves for a solar installation at 0 degrees E/W (on the Greenwich Meridian) and at a range of latitudes spanning the WPD operating area. The heatmap and plot shown are for 52N. The scaling for the solar response therefore assumes that a response value of 1 (at maximum) corresponds to the installed capacity of the system. In the plot below it can therefore be seen that at half hour datapoint number 20 (10am) on June 20th, the solar response is just over 0.8 of the actual solar installed capacity. This will be assumed for all connected solar installations at the target BSP closest to the requesting app user. The same lookup process can return a scaling value for any time (to half hour resolution) on any day of the year (all years are the same).

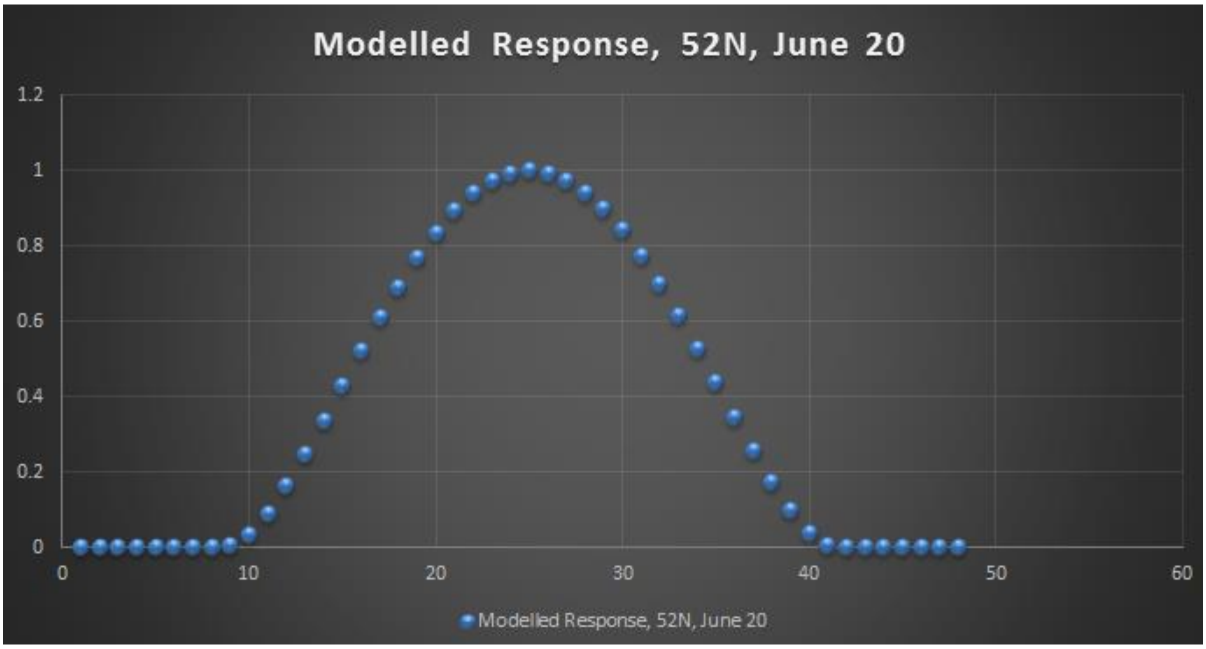



Figure 7 - Modelled Diurnal Solar Response Curve

### Handling of Local Time

As highlighted in the discussion above, the elevation of the sun at the solar generation site is a principal determinant for the level of generation from a PV site. It is therefore necessary to consider the local time rather than the civil time in doing the calculations to support the app. The civil time is defined across the whole country, so for example when it is 12:00 noon this is defined to be everywhere in the UK. However the country extends from east to west for several hundred miles and as the earth rotates over the period of a day, the time of local sunrise, sunset and local noon depends on where in the country the user/customer is located so that across the WPD operating area sunrise happens earlier or later than that indicated by standard civil time, for example, in Cornwall and East Lincolnshire these times can be quite different. Thus longitude of the app user determines their local time and how different this is from actual civil time[1].

An additional correction (of variable size), derives from the way the earth orbits the sun. This secondary effect, called the equation of time, also acts to shift the local sunrise, sunset

[1] It may be noted that the concept of a single national time standard was only applied in the UK after the advent of railway timetables in the early/mid 19th century. Prior to that period, towns and villages had their own true local times.

(etc.) times from actual civil base time. If the position of the sun in the sky were to be recorded precisely at noon each day throughout the year, it would display a figure of "8" shape known as the *solar analemma*. This is because it is clearly higher in the sky in summer than winter (accounting for the up/down change) and is either east or west of the meridian as a result of the equation of time making the sun early (or late) to culminate due south of the observers location. In the Carbon Tracer App the position of the BSP is taken to determine longitude of all generators in that supply area. There may be a small inaccuracy resulting from this as generators will, in general, be east or west of the position of the BSP.

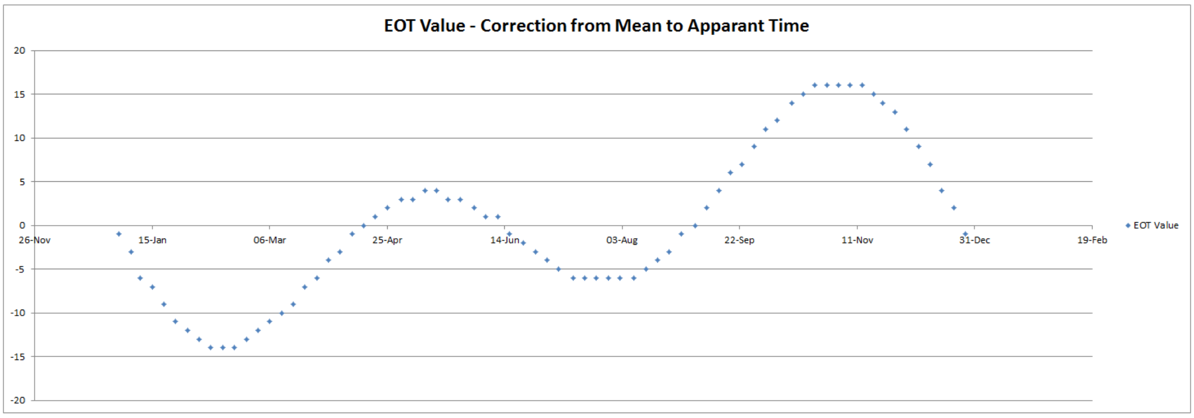



Figure 8 - The Equation of Time Correction Through the Year

Calibration of a sun dial requires both of these effects to be taken into account and together these can mean that local and civil time can be as different as 40 minutes at certain times of the year in some locations. It should also be recalled that summer time can add a further hour of offset from GMT for which all computations must be done.

## Scaling of Other Forms of Generation

Other forms of generation are more complex to scale and for this version of the app have been assumed to operate at just below their stated capacity using an empirical scaling value derived by another project. Scaling for generation from tidal barrages for example requires tide table input, while biomass incinerators may only operate at certain times of day so that scaling them would need operational timetables. This is a difficult issue as there may be significant variation rendering this area incapable of being modelled accurately.

Considering the various forms of locally attached generation (i.e. that which WPD manages as connected to its distribution network) the view below indicates the total amount of generation connected to the overall WPD network, broken down by generation type (values in MW taken from the generation summary file).

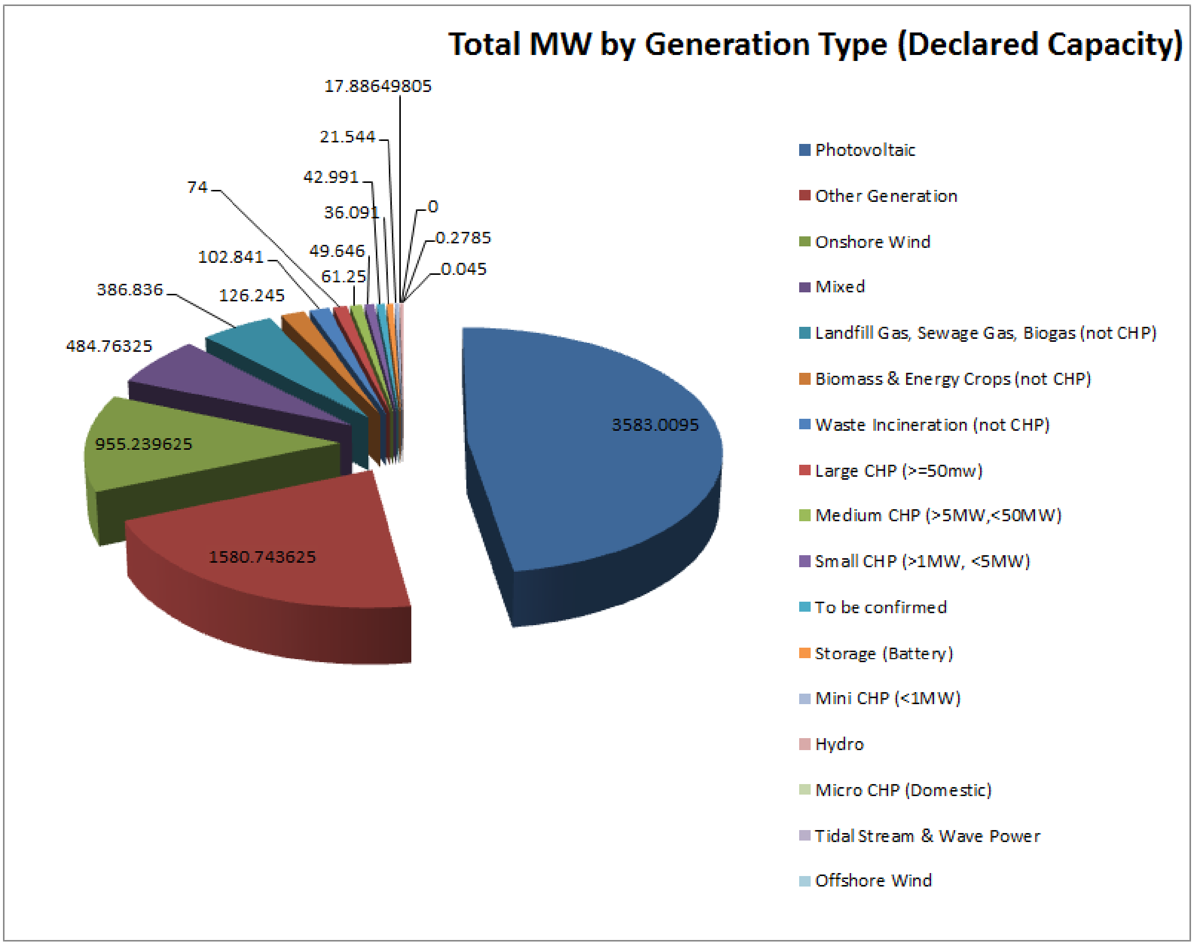



Figure 9 – Generation Capacity across all WPD by Generator Type

Clearly scaling of the solar photovoltaic and wind generation contributions deals with a significant amount of the above (some 60.3% overall) – so across all the possible locations where the app might be used, the scaling of these forms of generation is not only most straightforward of itself, it is also the most prevalent.

It does need to be recalled, however, that the relative contributions of all different possible generation types will vary significantly between individual sites so a user connected to a BSP which only has waste incineration generators may have a less accurate mix calculation and exhibit a poor carbon intensity[2].

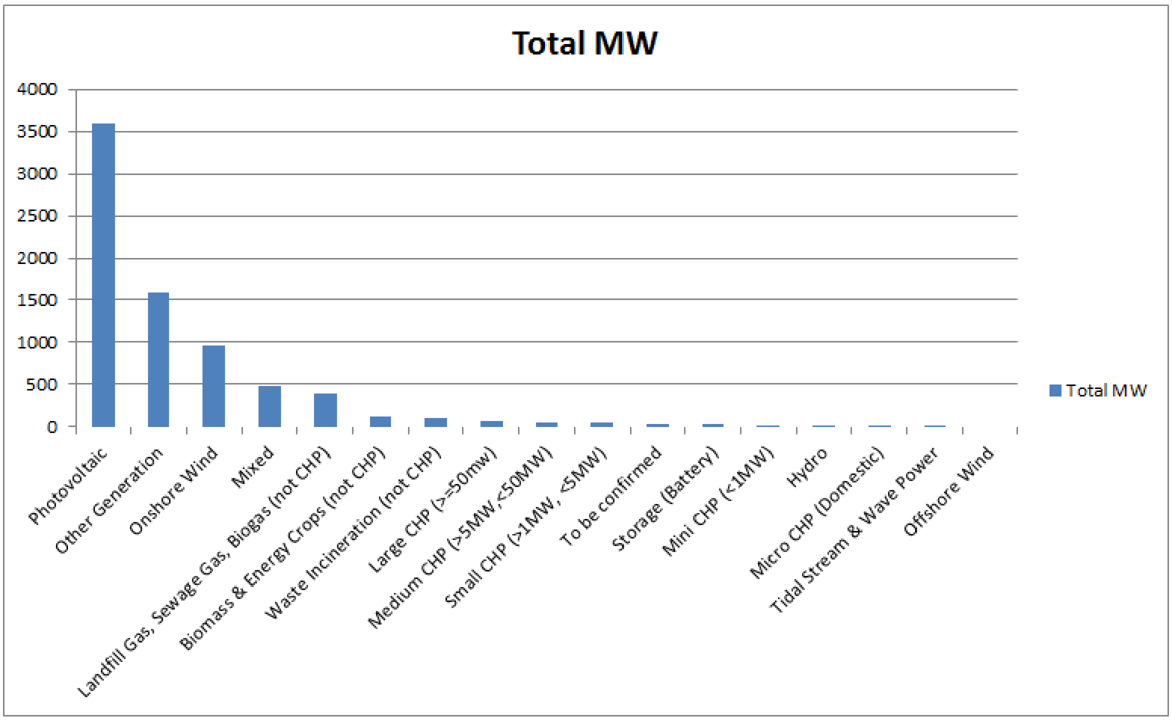



Figure 10 - Generators by Type

## Scaling of Load

The current app cannot take a real-time data feed showing load (net generation) at the BSPs as this would not be feasible at the present time and version. However with access to very good historical information concerning the network this allows for the classification of the various BSPs into different types based on the load, which itself derives from the number and sort of customers attached to the BSP. This work has been undertaken by a different WPD Project. The load types are currently defined as Urban, Rural, Mixed and Mid-day peaking and characteristic demand curves (called load profiles) are available for these at

[2] This was actually seen in the Cardiff Central BSP which was regularly the BSP with the worst CI value. When investigated it was found that a new waste incinerator had been commissioned in this location, it is called Trident Park and has a capacity of 30MW. With little other generation, this meant the waste plant dominated.

different times of the year (as there is a seasonal variation in the form of the load/demand). The template load profiles are *normalised* so that the curve values (daily curves with half hour resolution) are between 0 and 1 with 1 being the maximum value seen across all seasons. An example is shown below, from which it is seen that the maximum demand is seen in winter at around 18:00 each day.

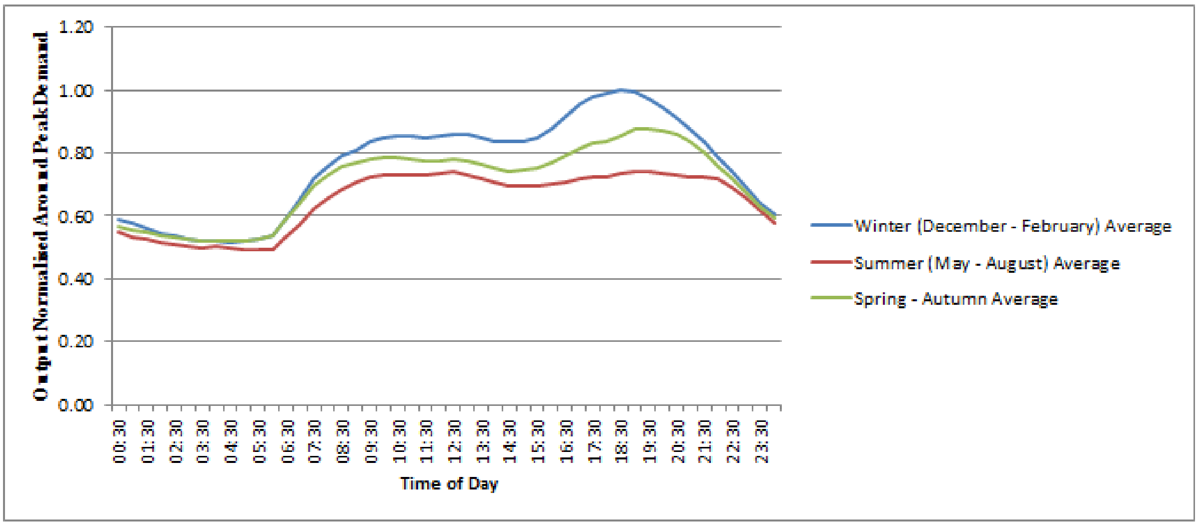



Figure 11 - Generalised BSP Load Profiles (Seasonal)

Thus, to obtain a view of the instantaneous load at a given BSP, it is necessary to multiply the current normalised load value from the template load profile for BSPs of that type by the maximum demand value for that BSP.

### Data Management

The App main control flow diagram in Figure 1 (above) also shows the main data files which support the operation of the system. The data files are as follows:

### BSP Metadata File

The BSP Metadata file describes the BSP substations included in the 4 WPD operating regions. For the app, all analysis is traced to the BSP level and every app user is therefore localised to the BSP within whose polygon area the users location is found. If a polygon contains more than one BSP (due to parallel operations) then the closest BSP must be chosen within that polygon.

This file is supplied from WPD as a CSV format file, comma separated. It is provided on a once only basis as it is not expected to change at intervals shorter than around 6 months as most of the data is fixed. The Max demand will change on an approximately annual basis as new analysis of this is done.

Having located the users ESA from the polygons as noted above, the app needs to look up all possible BSPs in that ESA within the BSP Metadata file. The users position can then be checked against the polygons to determine which one encloses the users location. This will give the Network Reference ID for the BSP to which the user is assumed to be attached. This Network Reference ID is a lookup key for other files in the app data file set described elsewhere in this document, and including the BSP Metadata file.

Having indexed into the file for the required BSP, all the necessary information for that BSP may then be obtained from the columns. There is a data row for each BSP.

### WPD Connected Generation File

This file is a TEXT file of type .TXT which is already uploaded to Enigma/Solsoft as one of the existing overnight files. It is described in the ICD document. The file contains the attached generation for all locations indexed by Network Reference ID. This includes all primaries as well as BSPs but primaries are not required in this implementation. The information is regularly updated and WPD maintain this information internally. Hence, this file is managed on a daily basis via the Solsoft interface for the Generation Capacity Website.

The Network Reference ID for the BSP obtained from the BSP metadata file is used to find all rows with this same Network Reference ID. There is a separate row in the file for each type of connected generation. The total connected capacity (column 3) is the sum of all attached generators of this type at all the primaries fed by this BSP plus the generators attached directly to the BSP, so is the total attached capacity required for the app. This value is a maximum and will later be scaled to account for prevailing conditions. Columns 4 and 5 are unused in this version although the file is assumed to catch up with the pending connections to include these in new versions as time passes and the file is updated.

### Wind Scaling Values File

This file is a CSV format file, comma separated. It is provided on a once only basis as it is not expected to change. The data was derived from the response and behaviour of a (typical) 300kW turbine and was provided by Carbon Trust. The response has been normalised to allow for use for any turbines given that the type and size of these is not known to the application which only has the total attached wind capacity.

Column 1 is the wind speed index used to locate the generation efficiency for that value contained in column 2. Therefore, given the prevailing wind speed in $MS^{-1}$ (obtained by query for the specified time on the weather data feed), look up the normalised power output taken from column 2 for the closest matching wind speed row (rounding required depending on the format of the wind speed data supplied by the weather data feed ).

The lookup is not required for average wind speeds read from Weather data feed which exceed 25MS-1 as the turbines cannot be used at speeds in excess of this value (this equates to around 56 MPH). In such cases the effective power output is therefore 0. This is because of the possibility of damage to the turbines in high winds. Refer to the diagram shown in Figure 5.

### Solar Scaling Values – Season and Time-of-day Response

Even given a completely clear sky and a transparent atmosphere, Solar PV output varies considerably with day-in-year (season) and time of day. The diagram below illustrates this. Summer response is, at least theoretically, highest and winter lowest, while spring and autumn are similar and in between the two extremes which occur at the solstices. Peak output is at local noon (see section on EOT time correction as this is not always the same as civil noon). There is a further dependence on the users latitude with the solar response decreasing the further north the user is located.

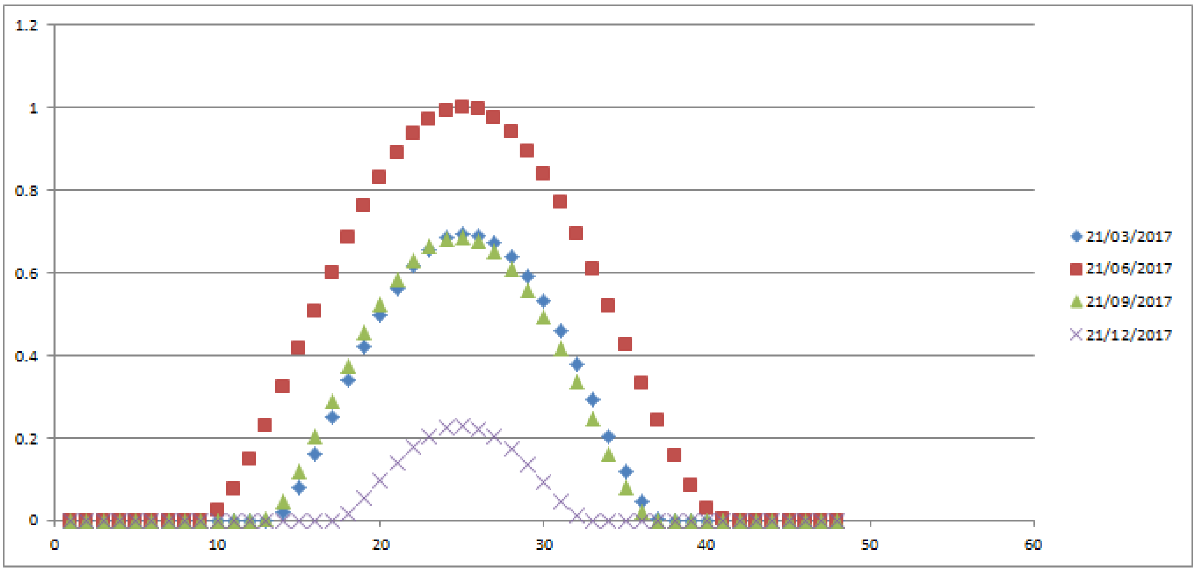



Figure 12 - Modelled Solar Response by Season

To deal with this, a set of modelled response curves have been created at 1 degree steps in latitude. A curve is available for each day in the year with 48 half hourly datapoints per day.

The app will obtain the latitude and longitude of the users BSP to which all results are reduced. The latitude must be rounded to the nearest degree and used to fix the curve set for that BSP. Five curve sets are available for latitudes 50 – 54 degrees N inclusive, covering the extent of the WPD operating regions with a curve set in each file.

To accommodate leap years, in this case it was suggested that Feb 29 uses the lookup for Feb 28. The app applies this correction before reading the data file. Thus there are only 365 response curve rows in the file.

The normalised value is used to scale the attached total solar capacity (as a multiplier – the normalised scaling factor) at the selected BSP to give the instantaneous value for the time of the call.

BSP Effective Solar Capability = BSP Attached Solar Capacity * Normalised Scaling Factor.

### Solar Scaling Values– Cloud Attenuation

Following scaling for season and date/time the solar output needs to be further scaled according to the cloud cover at the site. In the design this means for the BSP since the weather is determined (from the weather app) for each BSP.

A sample of around 60 solar parks has been checked for peak output on sunny, cloudy and rainy days. One example is shown below (8 March 2016 was very rainy in the SW; 17 March was sunny over much of the Southern British Isles. The image illustrates clearly the suppression of the output (the 9 day difference in time will have made the 17 March response slightly higher, the dates of the cloudy/clear days were chosen to be as close together as possible for this reason).

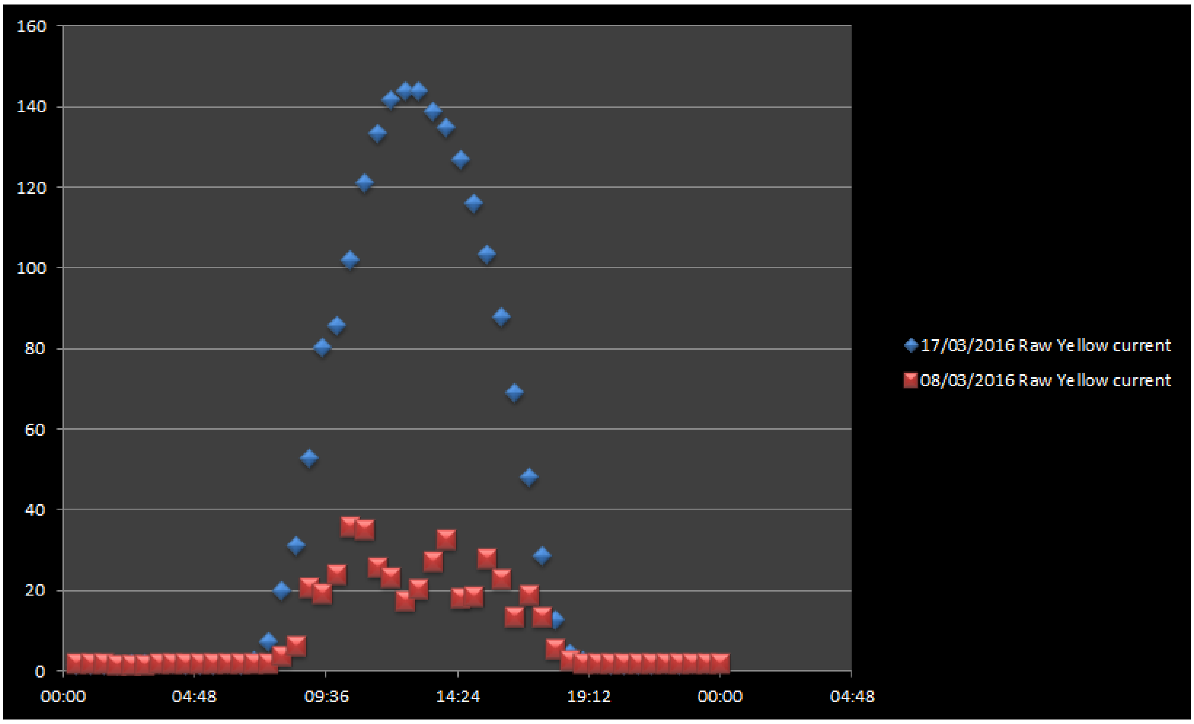



Figure 13 - Solar Response with Cloud Attenuation

The weather app returns the cloud cover as a fraction of the sky occluded by clouds in the range 0 – 1 and a rain value (precipitation intensity). These value can then be used to index into the cloud cover solar response file containing the solar VS cloudiness response curves to obtain the cloud scaling factor (if cloud only, column 2 is used to obtain the value, if rain present (at all) then column 3 is used). This is then used to further scale the solar effectiveness output from the season/date-time response step.

### Equation of Time Values File

The equation of time is a fixed correction for each day which needs to be applied to civil time to account for the eccentricities in the earth's orbit around the sun to return a true solar time. There is a row for each day in the year allowing for leap years. The correction is in minutes and has either a positive or negative value depending on whether the correction applies forward or backward on civil time. The correction is required because solar output is dependent on the position of the sun in the sky, with max solar output for any PV being at the time the sun culminates for a user (i.e. is due south from the users location). In fact as all data for the app is referred to the BSP, the time of local noon for max solar output is the time of culmination of the sun from the longitude of the BSP. The EOT correction (up to 16 minutes) must be added to a further correction allowing for the longitude of the BSP however this is a simple computation requiring just the longitude with an hour shift per 15 degrees of longitude. The two time corrections together can result in over 40 minutes time correction to obtain apparent time with respect to civil time for locations in the west of the UK where many of WPD's network and customers are located. Correction BST to UTC must also be carried out. The Equation of time as a function of date is shown below.

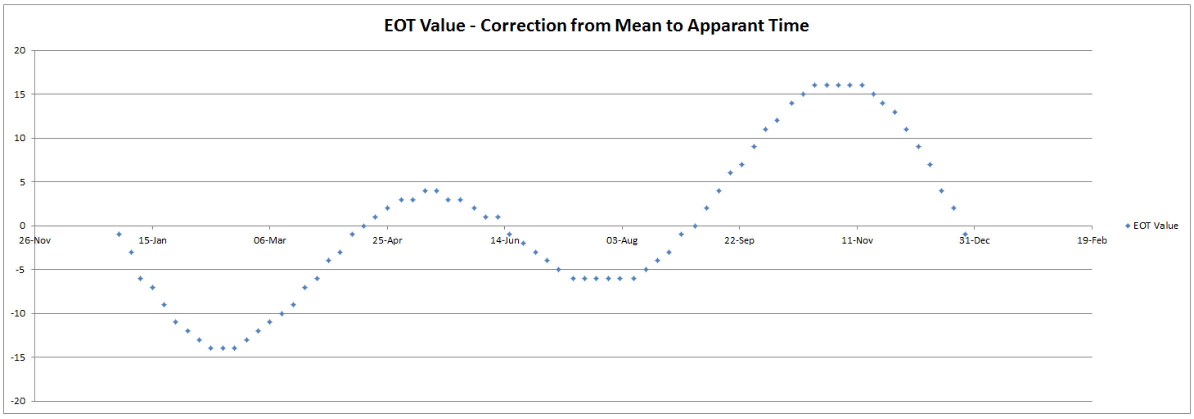



Figure 14 - The Equation of Time Value by Day in Year

The data is sourced from the UK Hydrographic Office, being astronomical almanac data. WPD have been granted a licence to use this data. The original is given in 5 day intervals and this has been reduced to 1 day intervals by a linear interpolation.

Prior to accessing the data the caller should convert current date to day-in-year. All times should be converted to UTC. The day number read from column 1 can be used then to locate the EOT correction for this day in column 2.

To calculate LST from LAT use the equation: LST = LAT - Long – EOT, (Where LAT = Local apparent time and LST = local standard time LST)

(or LAT = LST+Long+EOT)

> *Example: Find the universal time when the Sun is on the meridian at a place 1degree east of Greenwich on February 28.*
>
> *In units of time the longitude, Long = +4 (min)*
>
> *Using the table, the equation of time, on February 28 is EOT = -12 (min)*
>
> *The Sun is on the local meridian when LAT= 12h 00m.*
>
> *Therefore UT = LST = 12h 00m - 4m + 12m = 12h 08m*

The value of the total shift between local apparent time and civil time can then be used to determine which half hour bin to use from the solar response curves, this may be the previous bin in some instances.

### WPD Load Profiles Fileset

The load profiles define the demand at the BSP, however they are not available for each BSP. Instead the profiles are created per BSP type and all BSPs are allocated to a type. The types are Urban, Rural, Mixed Midday Peaking and are based on housing density. This approach is taken because the generation must be netted off from the demand to create a raw (true) demand value (WPD need this for planning purposes which is why this information is available to the project). Each profile is a 48 half hour data point curve, being a characteristic day. Four such curves are defined to cover four seasons. These are grouped by WPD region in the data file. The values are normalised (range 0-1) and to obtain the actual instantaneous load in MW, the normalised value returned from the file should be multiplied by the peak demand value read from the BSP metadata file for this

BSP. The profiles may change on an approximately annual basis as new analysis of this is done.

Working from the BSP returned from the initial location check, the region is obtained, along with the max demand value and BSP type from the BSP metadata file. For the current season (check date range in the load table below) and time (index into the loads) return the normalised load value. Use the Max Demand value along with the normalised load value to obtain the instantaneous load in MW.

### Fuel Types and CO2 Values File

Both the BMRS data feed and the WPD attached generation details are based on fuel types. These need to be classified and allocated to categories so that this information can be presented to the users. Each fuel type also maps onto an amount of $CO_2$ per kWh energy generated by this means.

The fuel type is used to index into the fuels table to obtain a number of values including the carbon intensity, the allocation to the types (renewable, fossil, nuclear etc).

### Development

With the Requirements Specified and high level design in place in a working note covering the main algorithm and the data, the responsibility for the production for both the app and website were handed over to Enigma for implementation. The first task was the production of a Functional Specification [Ref 3] echoing the design correctly. This was reviewed and approved and actual implementation in code then followed. This section is not covered in further detail here; however some of the recommendations for a potential follow on project are collected and presented elsewhere in this document.

### Testing

The bulk of the testing activities in the earlier project phases were carried out in-house by developers Enigma Interactive. This included their unit and integration tests and high level system tests on suitable hosts in-house.

WPD became closely involved for system testing, acceptance (for go-live), validation testing and finally in commissioning security inspection penetration check (*pen check*) via WPD IR using a third party specialist pen check organisation. WPD IR mandated a full inspection even though there was no connection to any WPD business systems and the data was non-personal and in some cases already accessible for the public. This approach was to guard against the possibility of an attack causing adverse publicity and/or reputational damage.

The report on the Pen Test revealed a small number of minor issues which were corrected. These are not detailed here for obvious reasons (although are available to be shared with other DNO's on request).

The host sizing exercise was carried out during this phase so as to secure the most appropriate server and dev/test support system with Hyve, the hosting organisation used by Enigma. The choice was made from several possible support "tiers" which ranged from 1-4 in an increasingly expensive increased specification system. The details of the chosen platform are as follows:

Managed Hosting Service for the live system: 1 x Tier 2 server of hosting capacity including:

- 2 CPUs;
- 6GB RAM;
- Up to 50GB webspace;
- Up to 500GB data transfer per month;
- Up to 40,000 outbound emails;
- Hardware firewall;
- 24/7 proactive website monitoring;
- Daily on-site AND offsite back-ups;
- Named point of contact at Enigma.

For the dev/test system, a lower spec system was deployed having:

- Up to 5GB webspace;
- Up to 50GB data transfer per month;
- Up to 4,000 outbound emails;
- Hardware firewall;
- 24/7 proactive website monitoring;
- Daily on-site AND offsite back-ups;
- Named point of contact at Enigma.

### Feature development and consumer engagement

WPD had previously developed the concept of carbon tracking which used power flow tracing methods to estimate local carbon intensity. This Carbon Tracing project looked to develop an app on the back of the power tracing concept and examine the extent to which users engaged with this. Whilst technically feasible, the concept of local carbon intensity was not borne out of user needs and so carried a risk in terms of engagement or lack thereof. It was therefore critical to keep the users at the heart of every stage of app development.

The team took an agile approach to developing the app, in order to make the process as user-centric as possible. The development can be split into 4 phases: Ideation, Wireframing, Prototyping, and Launch.

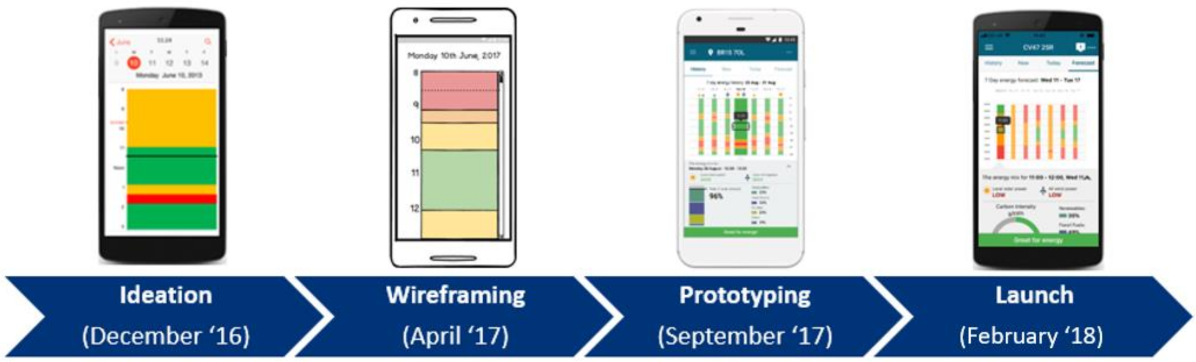



Figure 15 - Project Phases & Main Activities

## Ideation

The Ideation phase has previously been discussed in Section 4.1. In this phase, interviews were conducted internally with Carbon Trust employees as potential end users. Results found that even amongst the 'beach-head' segment (i.e. the part of the population that would be most interested in the app) that Carbon Trust employees represented,  a lot of work needed to be done in order to make the app engaging to end-users.

## Wireframing

Wireframing is a technique deployed by developers to create a mock-up user interface, which may be presented to potential users, internal stakeholder reviewers to help understand the overall navigation and look and feel within the app, without the overhead of designing a real app version. The project had initially included some provision for a more extensive form of early user review & feedback by using an early version of the app itself, but this approach proved unworkable within budget and the timescales.

Using the learnings from the research listed above and the outputs of the internal and external workshops and expert interviews the Carbon Trust developed wireframes to test different ways of using the data provided by WPD. These wireframes were developed using the Balsamiq wireframing tool[3].

The wireframes were tested with consumers across ten interviews, who were asked to provide feedback on which features they would like to see in an app. These consumers were recruited through the Carbon Trust mailing list. This feedback fed into the process to choose which features to progress to the app development stage, in addition to further interviews with experts. The prioritised features are shown in Figure 16. The key feature that interviewees were most interested in was Forecasting (both daily and multi-day).

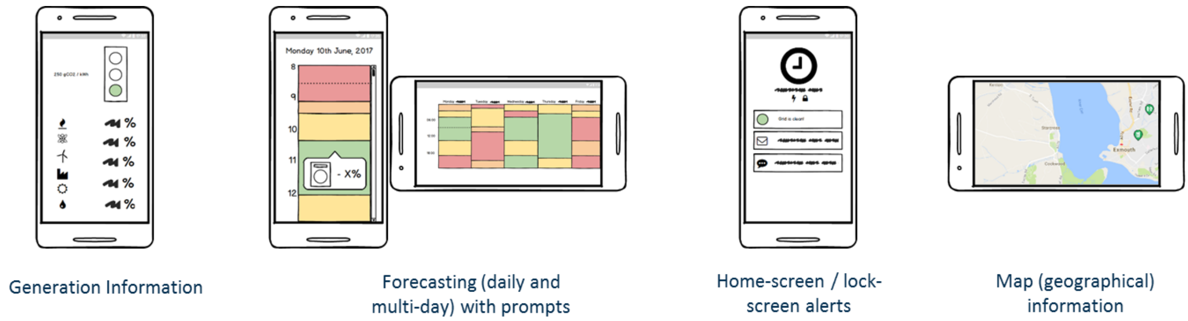



**Figure 16: Wireframes of prioritised features after feedback received during the Ideation and Wireframing development stages**

## Prototyping

During construction of the app a 'prototype' was created by preparing a set of screenshots as "sample screens" and linked together into an app-like system using *Marvel*[4]. This prototype can be deployed to the end-user host platforms and simulates the behaviour and appearance of the subject app itself (in this case Carbon Tracer). This allows various audiences to provide their feedback and gives the developers a good idea of where to concentrate development work, all without the overhead of preparing, deploying and hosting a fully tested system at an early enough stage.

[3] https://balsamiq.com/

[4] https://marvelapp.com/

The Carbon Trust tested the prototype (Figure 17) through phone interviews and online surveys. In total, 26 people were interviewed including 20 members of the public and 6 employees with an affiliation to the project from WPD. Most of the 26 interviewees represented the beach-head segment, i.e. those most likely to both engage with and understand the app, for example those involved in community energy.

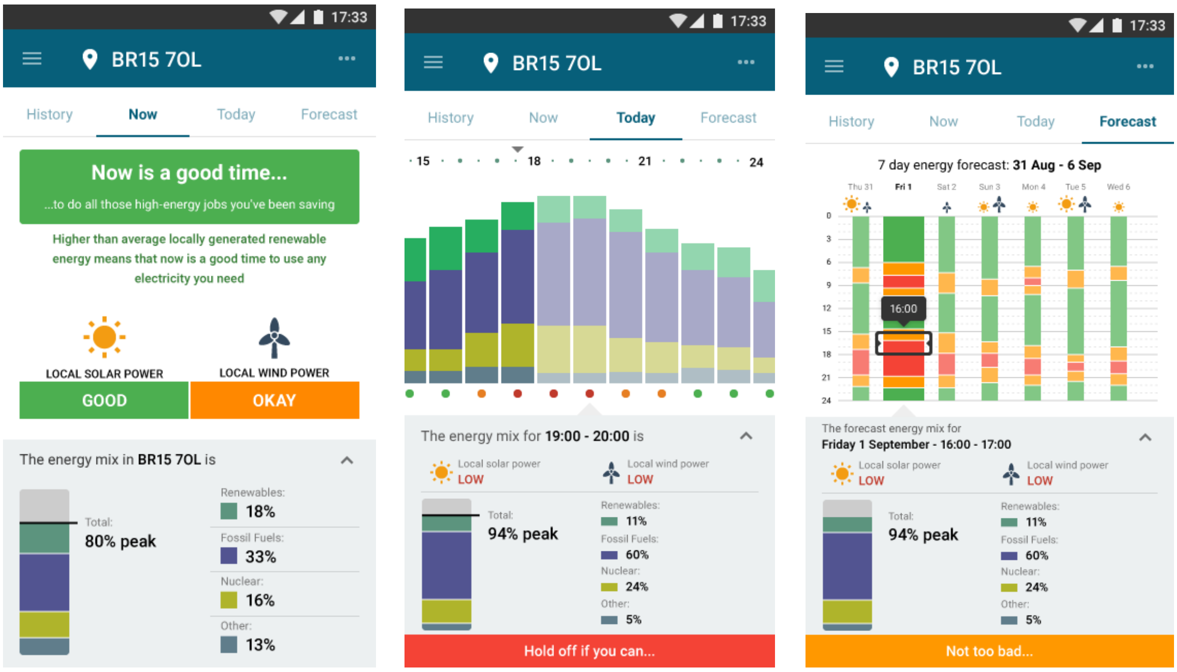



Figure 17 - Marvel Wireframe Renditions of the App (Now, Today and Forecast features)

The 20 members of the public had responded to a survey posted through multiple channels online, including the Carbon Trust mailing list and community energy groups' newsletters. Those interviewed all had an interest in local and clean energy, and had a relatively high level of understanding of the domestic electricity sector.

An open structured interview was conducted to gather feedback and score engagement on individual features of the app. A survey was sent after the interview in order to gauge holistic understanding and engagement in app. This was a small sample size, and results were viewed with caution.

The key learnings from these interviews were:

- The high-level message communicated through app was slightly misaligned. 'Carbon intensity' was being mixed up with 'amount of (local) renewables', which isn't necessarily a valid proxy. In addition, some users understood banding/messaging to be based around 'demand'. The 'energy mix' column in the bottom half of the screen, with widespread confusion as to what the '% Peak' annotation meant;

- The app is engaging to the beach-head segment, but is not (initially) easily understood by them. Less technical viewers find the app harder to understand. This implied that simplification was required across all features of the app;
- The forecast feature was the most engaging feature to those who were interviewed. Interviewees' were interested in being able to plan future electricity usage (e.g. the use of a washing machine). The Now and Today features were also seen as engaging, while the History screen was seen as not particularly engaging;
- There is a disconnect between the messaging at the top of the Now feature (e.g. "Now is a good time…" and the Local Solar Power and Local Wind Power statuses. For example, the feature may suggest that the overall carbon intensity is very low and that it was therefore a good time to use energy, however the local wind and solar power was said to be 'Low'. This caused confusion amongst users.

Prolific[5] is an online platform that allows researchers to find participants for academic or market research surveys, and provides pre-screening abilities to source people only from specific geographies (amongst other traits). It provides a flexible, scalable, cost effective tool for recruiting a more diverse audience than those sourced for interviews to test aspects of the app via online surveys. By including questions on demographics, attitudes and behaviours, results would allow the construction of user segments that could help target potential users of the app during the online marketing campaign for the app's launch.

A small trial was set up that recruited participants through Prolific to complete a survey using Survey Monkey. A survey was created that asked questions on the user's understanding of and interest in the introductory screens and the forecasting tool. The survey also asked some basic demographic and behavioural questions. The aim of this trial was to assess to what extent the results from surveys completed by participants recruited through Prolific could be used as a form of feedback at a larger scale once the app was released.

Fifteen participants were recruited at a cost of £1.35 each to complete a survey that was estimated to take around 5-10 minutes to complete, and the results were ready within 2 hours of the survey being published. The results showed that the Prolific platform could be used as a resource for acquiring feedback after the app had been launched, as the feedback provided in the survey aligned with that gathered during the telephone interviews.

[5] https://prolific.ac/

### Launch

The Carbon Tracer app was released to the public in February 2018, available to devices running Android and iOS and a web version was published on the WPD website.

Feedback on the app was generated through further telephone interviews and online surveys, outlined in more detail later in this document (Analytics and Feedback). Findings from this feedback stage will be useful in a future iteration or update of the app.

### Host deployment and Submission to App Stores

Note: The host sizing exercise was carried out before reaching the actual deployment activity so as to secure the most appropriate server and support system with Hyve, the hosting organisation used by Enigma.

Two Hyve environments were used for supporting the system – a lower spec dev/test host and an operational host with higher specification and associated support costs.

The user front-end for the apps had to be downloaded from the necessary app stores with Apple or Android depending on the users' handset. The Android deployment proved much simpler to manage, with the Apple App store requiring more extensive validation by Apple themselves before they would approve the App to go-live via their store.

These complexities meant that beta testing using handsets in advance of actual formal deployment being possible required the use (on Apple devices) of a support environment called "Test Flight". Users making use of this facility had to be set up by an App Development Team Manager and invited to participate in the testing programme via an email sent to their iTunes associate account. The full app in beta test format could then be downloaded to the handset and put into test.

## 4.6 Marketing

The marketing campaign involved two key aspects:

1. **Identifying the target audience**(s), defined as those who be interested in the app / the concept of location specific carbon intensity. Throughout the project it had become clear that the key target audience were those that were already engaged in green energy issues and also those who were interested in their local energy system.

2. **Engaging with the highest proportion of this target audience in the most effective manner, by delivering a well-executed and appropriate marketing campaign**. Three

aspects were investigated: the marketing channel, the branding used in adverts (WPD, Carbon Trust, or neutral) and the message communicated in these adverts

Three different paid marketing channels were assessed: Facebook, Google Adwords and Direct eMail (Figure 18). Due to the small budget available for paid marketing (~£4,000) it was concluded that Facebook would provide the most useful service. Facebook adverts allowed the team to test different adverts across different segments and see which adverts were more successful, allowing the team to learn and improve their marketing strategy during the campaign itself.

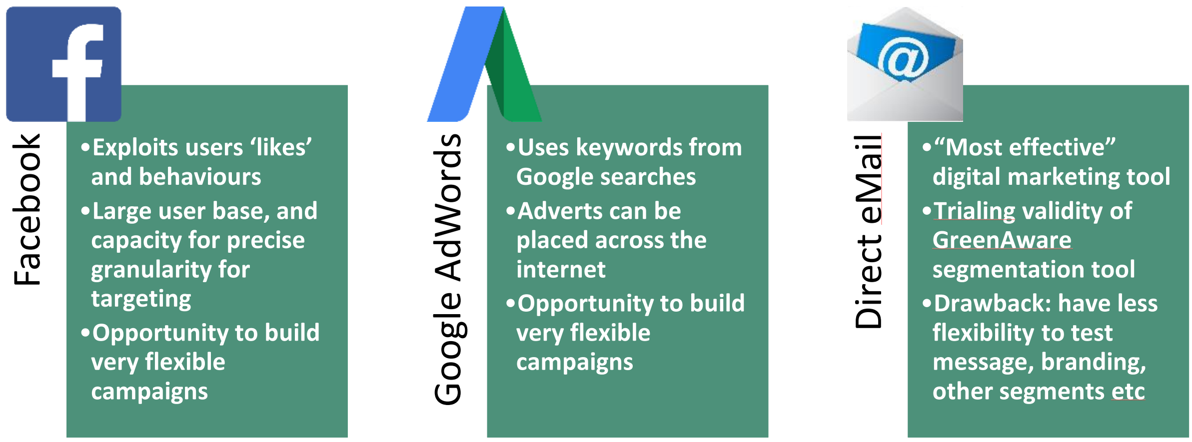



Figure 18: Assessment of the different paid marketing channels

In order to refocus the project on the actual development, the level of formal paid-for marketing was reduced for the launch. The following channels were used:

| Owned: Carbon Trust & WPD Channels | Earned: Carbon Trust outreach | Paid: Carbon Trust paid channels |
|---|---|---|
| • Newsletter<br>• Facebook<br>• LinkedIn<br>• Twitter<br>• Press releases | • 20-25 community energy groups<br>• 2 Local Councils | • £3700 spent on Facebook marketing campaigns<br>• 5 different advert/audience combinations tests |

Carbon Trust drove the marketing campaign across three strands: owned channels, such as the Carbon Trust mailing list and social media accounts; earned contacts sourced through various community energy groups in WPD's regions who spread the word about the app to their members; and through a paid marketing campaign on Facebook.

WPD also conducted its own advertising for the app. This included a coordinated press release with the Carbon Trust, WPD Facebook page posts (first week), and a Carbon Tracer dedicated link from the carousel to the WPD website innovation page.

Figure 19 below shows the number of new Carbon Tracer users over time, annotated with key events. The app was announced by WPD on the 5th of February and by Carbon Trust on the 7th February across their social media platforms. Carbon Trust also announced the launch of the Carbon Tracer app directly to 20-25 community energy groups in WPD regions that had agreed to help communicate its launch to their members around the same time.

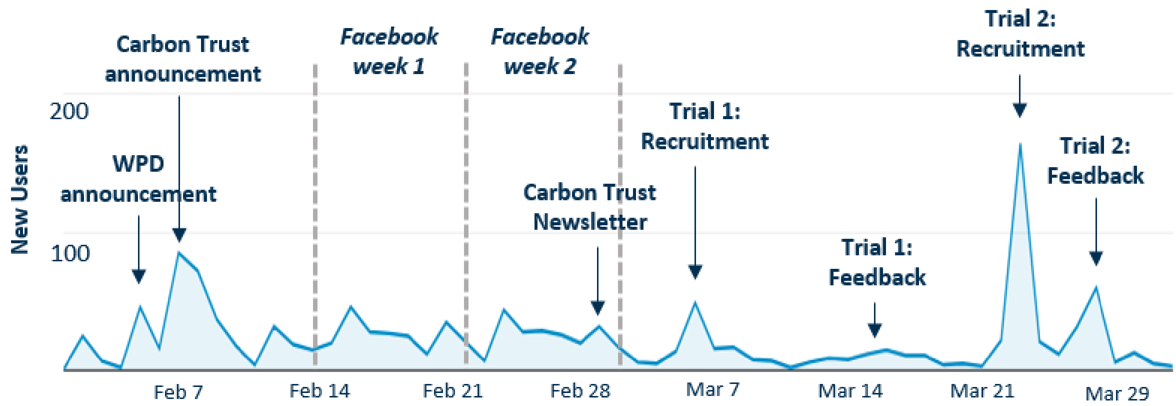



Figure 19: Number of new users of Carbon Tracer from February 1st to April 1st

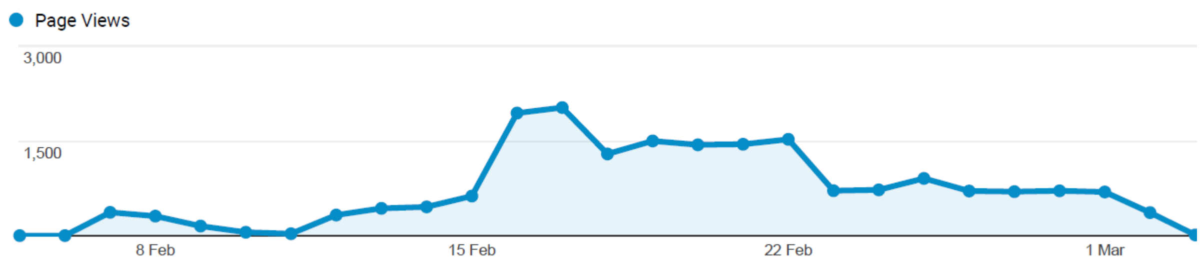



Figure 20: Number of visits to the Carbon Trust's landing page for the Carbon Tracer app before and during the paid marketing drive

Figure 20 shows page visits to the Carbon Trust's landing page for the Carbon Tracer app over a 30-day period. The paid campaign started one week after the launch of the news piece (7th February) with two core objectives: to drive traffic to the main landing page (to explain the app in more detail) and to encourage downloads of the app specifically amongst residents in the WPD distribution zone.

Two initial audience targets were set:

1) Broad geographic targeting that included adults (18 – 65+) within the WPD distribution area who had interests around academic institutions, sustainability and environmental protection;
2) A niche target within the same region and age range with more specific interests around renewable energy.

The launch of the paid promo campaign created a spike of interest, traffic to the Carbon Tracer landing page, and app downloads, yet this initial level quickly declined. In order to reverse this, new ad variants were created and applied across the existing target audiences. Alongside this the daily ad spend was also experimented with, tweaking the amount to ensure the largest number of people possible were reached in a 24-hour period while avoiding campaign overspend. These changes were applied to both broad and niche audience targets and it was the broad audience option that started to pick up more. Building on this, the final combination of all these changes was the campaign variant that had the most efficient spend and cost efficiency. This brought the average click spend down to £0.32/click from £0.50/click. The most successful ad variant is shown in Figure 21.


Figure 21: Screenshot of mobile ad variant that resulted in highest level of interest during paid marketing campaign

Broad targeting on social media is usually more cost effective than niche targeting, so it is unsurprising that when the audience size was expanded in the second week the ad spend became more efficient. This, however, is often at the cost of quality, which is why it was decided to go with a niche set at the start of the campaign. Broadening out the audience in this instance helped to drive more traffic to the landing page and maintain the level of app downloads during the period.

The Facebook campaigns resulted in a reach of over 250,000 people across WPD's distribution area within a two-week focused campaign period for a cost of £3700. No other traditional sponsorship opportunity would have made that impact for that small sum within that timeframe.

## 4.7 Live Operations & Support

Go Live required the following coordinated activities:

| Action | Who |
|---|---|
| Initial Host environment ready for sizing tests | Enigma |
| Name finalised | All |
| Support arrangements decided | WPD |
| Ready for end to end tests – User testing; Load testing; Sense checking | Enigma |
| Front end testing and changes completed | Enigma |
| Pre-population of weather data begins | Enigma |
| App submitted to Apple for verification | Enigma |
| Testing in Host Environment Complete and final host environment ready | Enigma |
| Final Approvals – WPD | WPD |
| Analytics collection prepared to go | Enigma |
| Digital marketing commences | CT |
| Formal Release | Enigma |
| WPD/CT Coordinated Press Release issue & social media announcements | WPD |
| WPD Website changes live | WPD |
| CT Mailing lists informed (and Press release issue) | CT |

The operations phase runs on from the go-live and extends out beyond the initial project. The Operations and Support phase is only just commencing at the time of writing of this Report. Additional analysis of user feedback and app and website analytics will feed into a further report on User Behaviour, see below.

As well as obtaining the necessary corporate sign-offs to go live with the App, the Customer Contact Centre management were also notified so that they could be ready for any incoming customer queries or comments. The Project Manager was nominated as the final resort contact for any issues which could not be fielded during the call.

### Analytics and FeedbackOverview of methods

It was possible to draw on four key sources of information directly or indirectly from users as follows:

- Ratings and reviews on the app stores;
- Carbon Trust direct telephone interviews with selected individuals;
- Online survey feedback;
- Google analytics data.

### App Store / Google Play

Looking at the ratings and reviews of the app on the App Store and Google Play can give generalised feedback on how the app was received by users who downloaded it. This was periodically checked to see how many reviews and ratings were being given.

### Telephone interviews

Ten feedback telephone interviews were taken with members of the public who signed up by following links to a Survey Monkey Poll put at the bottom of promotional material and advertised on Twitter, Facebook and LinkedIn.

The telephone interviews were useful to get rich feedback by engaging in a ~30 minute conversation with the interviewee to gain detailed information on usability and engagement of the app. The basic structure of telephone interviews (below) was kept consistent in order to increase reliability of feedback and this was:

- Introduction to the app and Initial feedback from the interviewee;
- Feedback on the major features of the app (Now, Today, History, Forecast);
- Recommended improvements from the interviewee;
- Higher level learnings and general discussion of the app as a concept.

The interviewees were generally very well engaged with local energy generation, with many of them being members of community energy groups or working within the wider energy sector. The telephone interviews were an attempt to validate our initial impressions of the app and inform the questions asked in the feedback surveys.

### Online surveys

Online surveys were designed and implemented in order to gain a wider selection of quantitative and qualitative feedback. The trial was undertaken in two phases with an initial trial of approximately 50 people to assess the value and richness of the feedback. Participants were recruited using Prolific.ac in the same way as had been done in the Prototyping phase described in Section 4.5. Following the first phase and initial analysis of the feedback, the results were considered useful enough to do another phase, recruiting approximately 200 people. In total, 249 people responded to the online surveys.

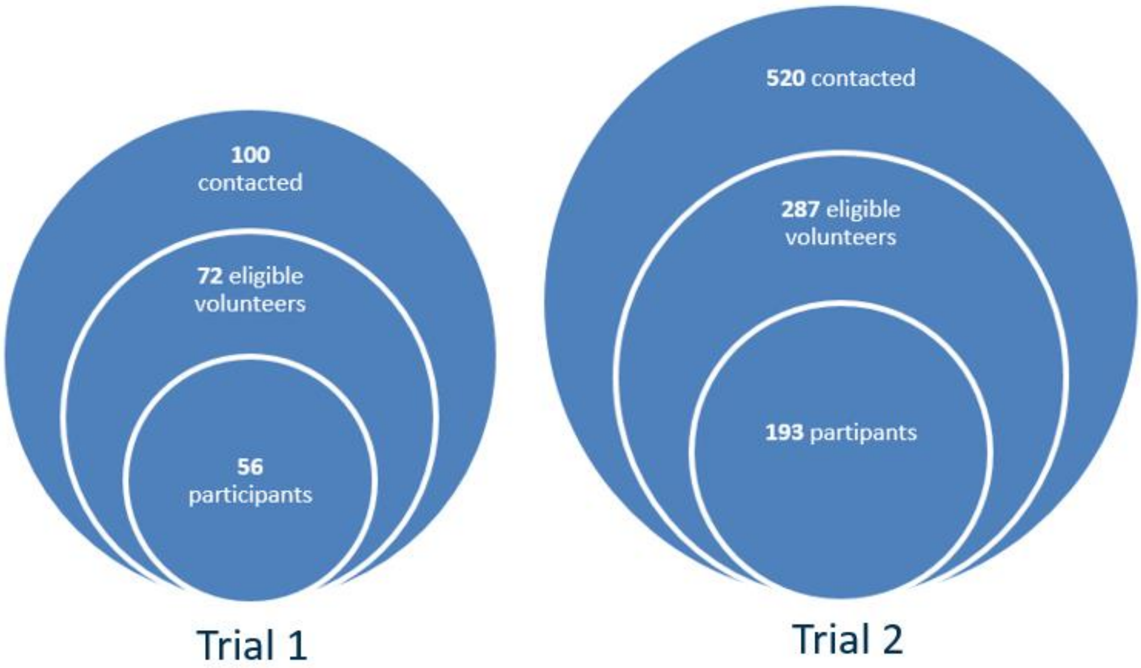



Figure 22: Representation of Trial 1, which took place over 25 days, and Trial 2, which took place over 4 days

Participants were asked questions encompassing the following:

- Basic demographics;
- Attitudes towards relevant topics (e.g. to what extent do you consider yourself an environmentalist?);
- Whether they wanted to be part of a trial (with links to download the app available).

Following this, those that responded positively were recruited to another trial, which asked detailed questions about the features of the app on a survey that was created in Survey Monkey. This survey asked a variety of questions, including:

- Feedback on each of the four major features;
- Feedback on the app as a whole;

- Questions to test awareness of topics related to the energy system.

Quantitative feedback was gathered through the use of Likert scale responses and employing the UPscale (see below). In addition users were encouraged to provide their opinions on areas of improvements and other feedback in text boxes.

Usability and Engagement was measured quantitatively using the Usability Perception Scale[6] (Upscale) which has been developed to assess the usability of eco-feedback and behaviour change on energy usage. The questions asked revolve around two key indicators of successful eco-feedback, usability and engagement. The questions alternate positive and negative statements which participants are asked to state whether they strongly disagree, disagree, neither agree nor disagree, agree, or strongly agree (a 5-point Likert scale). Examples of the Questions asked are given below:

| Usability | Engagement |
|---|---|
| I am able to get the information I need easily from this feature | I gained information from this feature that will help me how I use my electricity |
| I think this feature is difficult to understand | I do not find this feature useful |
| I feel very confident interpreting the information in this feature | I think I would use this feature frequently |
| A person would need to learn a lot to use this feature | I would not want to use this feature |

The responses are scored ("Strongly agree"= 5, "Strongly disagree"= 1, etc.) and by averaging the responses across recipients, a score can be ascribed to each feature for Usability and Engagement. This allows a comparison to be made across features as well as the ability to test how different population segments feel about the app.

The participants involved in the surveys provided self-assessment scores that suggested mildly pro-environmental attitudes, and a mild interest in local energy systems, and that

[6] B. Karlin and R. Ford, 2013, *The Usability Perception Scale (UPscale): A Measure for Evaluating Feedback Displays*

they are technology literate. There was a range of ages, and approximately 75% of the participants were female.

### Google analytics

This area fell within the remit of the Carbon Trust and had only limited scope following the project reshaping which reduced the interval following actual app deployment. The principle objective to be satisfied here was the project requirement to assess the "extent to which customers are prepared to engage and even modify their behaviour in response to improved information on Carbon Intensity". To achieve this most effectively, the project had to implement a modest enhancement which could reward them for delaying their appliance use possibly to a greener time slot. There was no possibility of verifying their actions, so this function was honesty based, and the reward system was an improved "score" which was flagged in a rosette on the main page.

The app was instrumented to gather analytics which could be analysed by Carbon Trust. To do this and correctly set up the analytics on Google for the app and website, it was necessary for WPD to pass the Google ID to the developers Enigma for the container within google analytics that was in use by the organisation. This tells the code where to send the usage data on the server side. The results of this work are presented below.

### Feedback

Overall (General feedback) The app was well received on both the App Store and Google Play with engagement by some of those who downloaded it rating the app out of 5. The ratings for the separate platforms are as shows[7]:

- App Store: 4.4 stars from 7 ratings
- Google Play: 4.8 stars from 10 ratings

The positive scoring suggests that users enjoyed the app, and this was reflected in the reviews which were generally positive. As there were only a low number of reviews made results should be taken with caution, however the lack of negative reviews (1 out of 17) suggests that there were no serious failings.

Feedback from the telephone interviews and online surveys also suggested that the app was received positively and as something innovative and unique in the market. Feedback

[7] Reviewed on 20th April 2018

showed 60% of online survey participants would recommend the app to a friend, and 65% would consider using the app to change behaviour and use low carbon energy more often.

Feedback showed 62% of online survey participants said they used the app between 1-5 times during the trial, regardless of the length of the trial. 10% used it more than 5 times and 20% used it once. 8% of respondents hadn't used the app since the first survey when the second survey started.

Participants in the online trial were asked to provide a self-assessment score using a sliding scale (with an associated score of 1-100) in answer to the following three questions:

- Do you consider yourself to be an environmentalist?
- In your own opinion, how "tech savy" are you?
- To what extent are you interested in your local electricity supply?

Using the answers to these questions, it was possible to segment the respondents into four different groups across each topic (interest in local energy system, pro-environmental attitudes, and technical literacy). Figure 23 shows the result of this exercise.

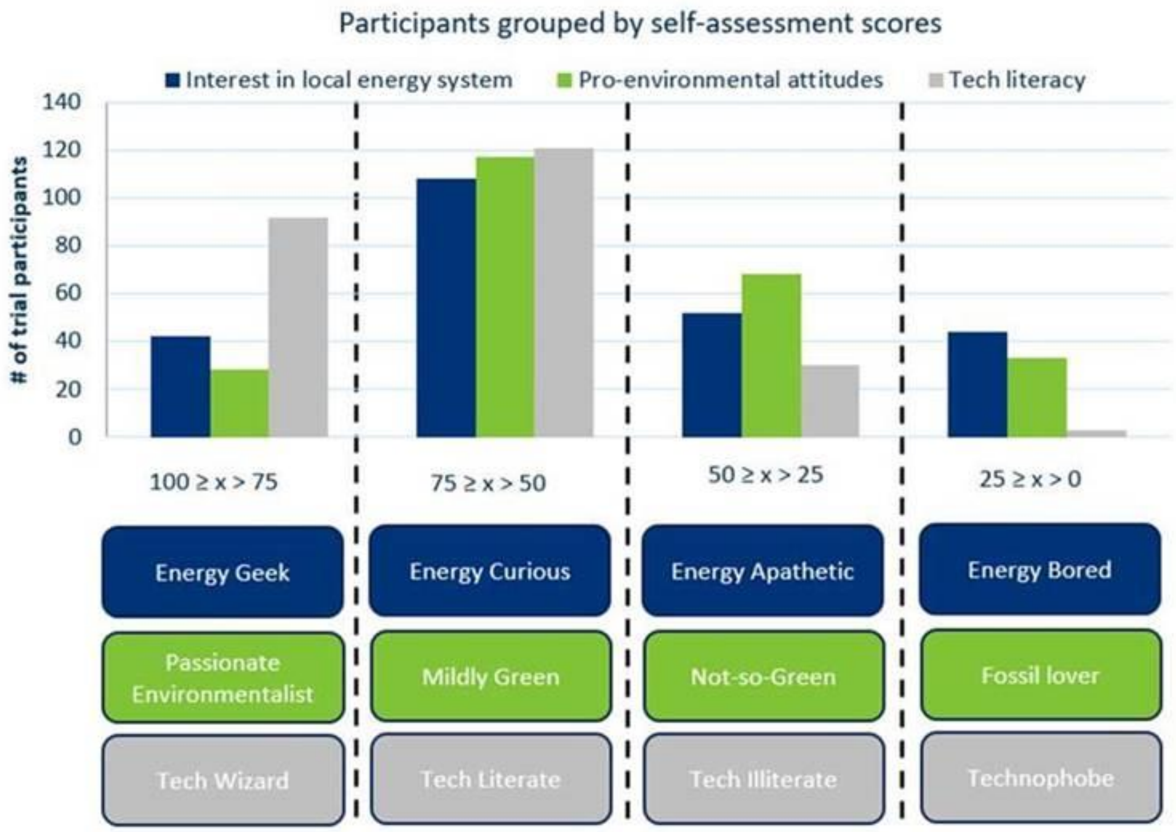



**Figure 23: Responses to the self-assessment questions related to the participants interest in local energy systems, their environmental attitudes, and their confidence with technology.**

Figure 24 shows the results of a question that asked participants to what extent they were engaged with the app on a scale from 1 to 100, with 1 equating to the response “I had no interest whatsoever” and 100 equating to the response “I found it very engaging”. These results were segmented according the groupings defined in Figure 23. They show that the app was engaging to all users. They also show that the app was most engaging for users with pro-environmental attitudes and for users with an interest in local energy systems (i.e. the beach-head segment), justifying the hypothesis that the app would be most engaging to these audiences.

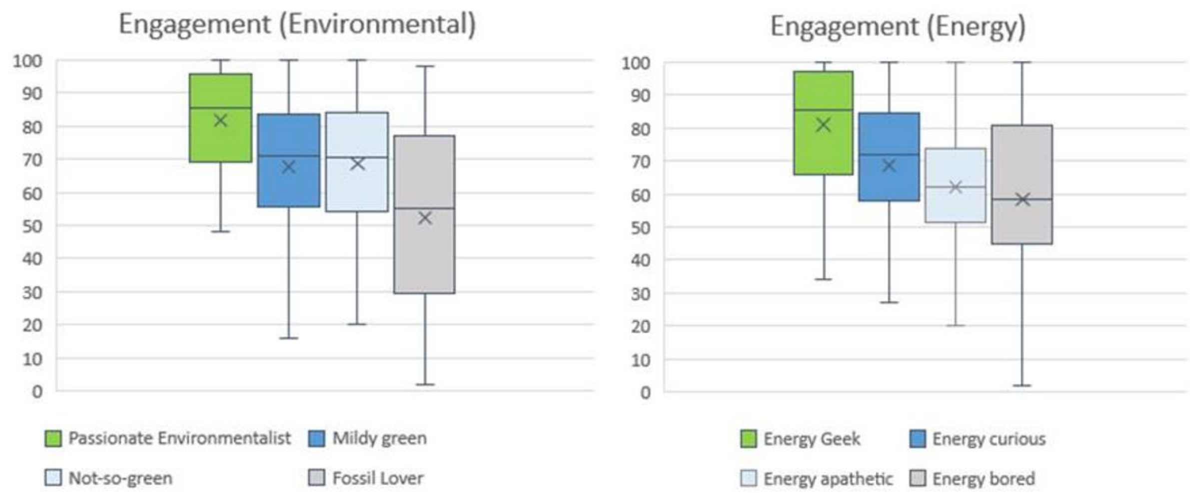



**Figure 24: Online survey participants' responses to 'To what extent are you interested in what the app was showing you?' with results segmented by environmental attitudes and by interest in local energy system**

Overall, usability and engagement of each feature was between ‘Neutral’ and ‘Positive’. This suggests mild engagement and understanding of the features in the app. The Forecast and History features were marginally less engaging to users compared to the Now and Today features. The Today forecast was the marginally the most engaging feature, and from comments received it is likely due to the do the fact users were able to use it to potentially change their energy use during the day (e.g. by delaying the use of their washing machine).

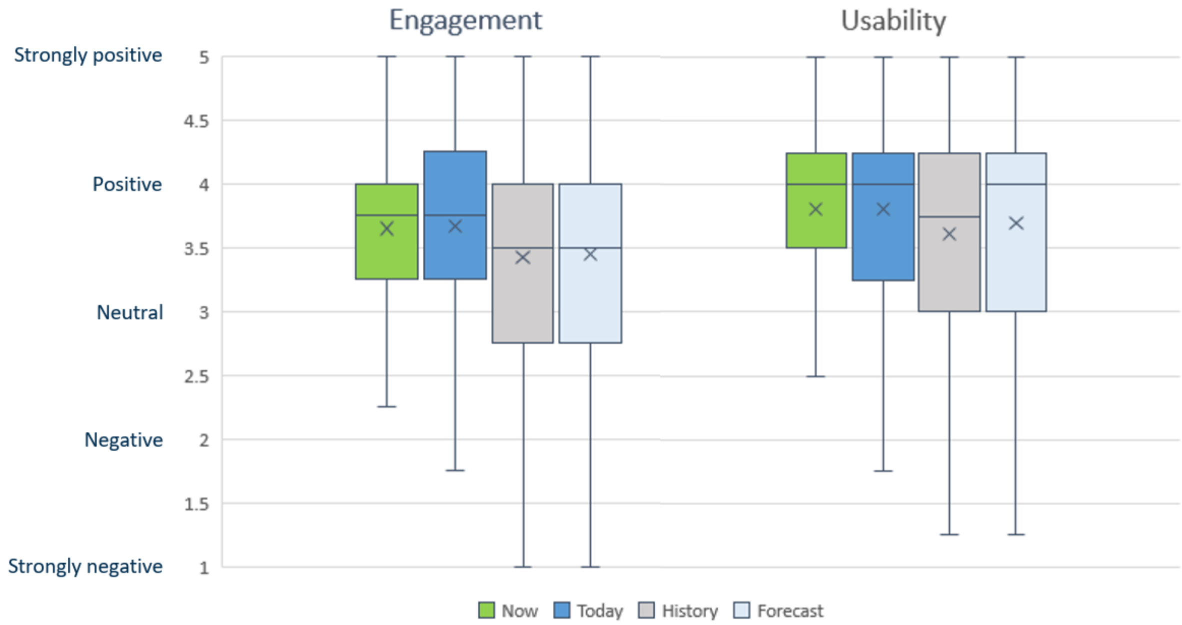



Figure 25: Mean usability and engagement scores for each feature using UPscale

Household income was not an obvious indicator of engagement or usability of app. Further analysis is required to corroborate the initial hypothesis that rural households are more likely to engage with the app than urban owing to more visible energy generation in those localities.

Individual awareness of the local energy system increased in 95% of online survey participants as a result of using the app. Participants were asked 'To what extent has using this app increased your awareness of your local electricity system?'; 49% answered 'a lot', with 46% answering 'a little bit' and 5% answering 'not at all'. Awareness among online survey participants increased across almost every indicator as a result of using the app (Figure 26). This was tested by questioning participants' awareness of several statements related to the energy system in the initial survey before participants had used the app and then asked the same question again after they had used the app.

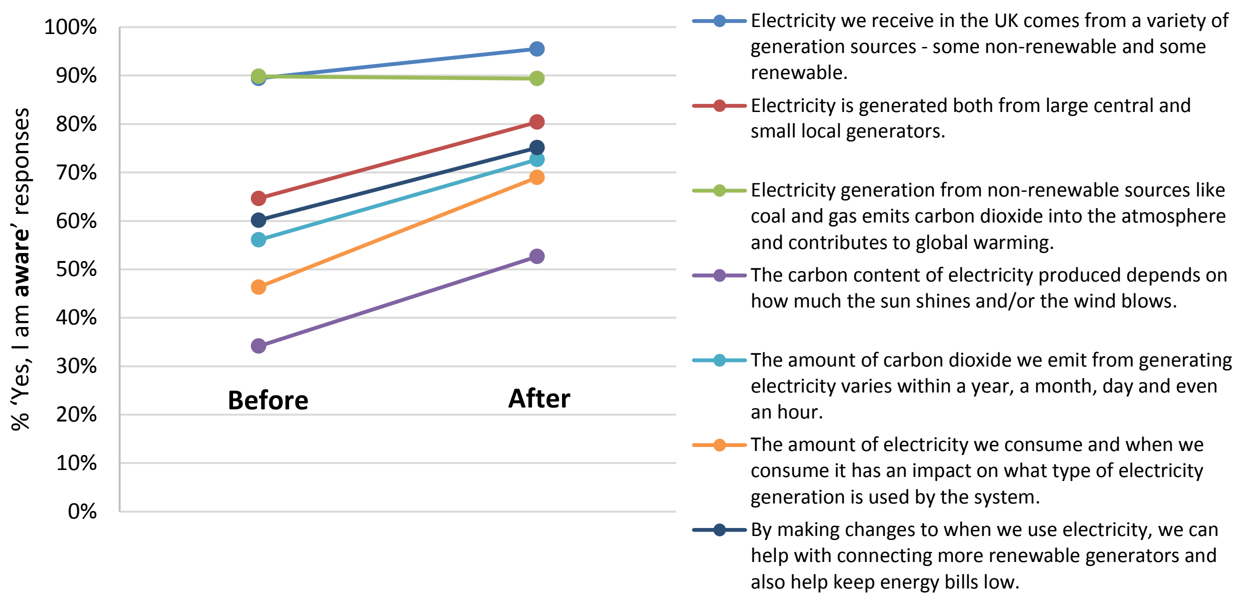



Figure 26: Proportion of positive responses to questions related to awareness of energy systems tested before and after users had trialled the app

## Key feedback of major features

During the phone interviews participants were asked about any improvements or learnings that could be taken forward in future iterations of the app, while the opportunity to leave qualitative text feedback in the surveys saw many participants take the opportunity to recommend how the app could be improved. The key pieces of feedback and recommendations are summarised below:

| | Positives | Negatives | Recommendations |
|---|---|---|---|
| Now | • Good **overview** of current energy mix and when a good time to use energy is<br>• Simplistic and easy to understand<br>• Most used screen according to Google Analytics (although as this was the "first" | • The **split of the page** was hard to use: scrolling down to reach the energy mix and intensity was fiddly<br>• Lack of engagement with carbon intensity as a metric<br>• Disappointment at **lack of suggested times** to | • Make the interface fit into **a single screen** without having to scroll to access all the information |

| | | | |
|---|---|---|---|
| | screen viewed by users this is not a surprise) | use green energy | |
| Today | • Described as the **most easy to understand** screen in the online surveys | • Having to **scroll** down on the screen when it could all fit on one<br>• Lack of Y-axis scale on the main bar chart meant some users found it difficult to understand what the information was showing<br>• Some did not like how the Today screen visuals were different from History & Forecast | • The **Now and Today screens could be merged and simplified** as there is significant overlap |
| History | • Interesting as a feature<br>• Interactive element was well received | • Lacking in relevance for many as it does not help make decisions on **future energy usage**<br>• Presents different data than what was expected from Forecast screen when looking back, leading to mistrust of data | • See what an **average week** is like, aggregated over a longer period<br>• **Flip the axes** to make it the same as the Today screen |
| Forecast | • Earlier feedback from interviews with beach-head segment suggested it would be the **most important feature** for them if it was accurate<br>• Allows you to plan your energy usage in advance | • **Issues with data resulting in consistent red or amber or green blocks -** problems with forecast led to minimal variation between 'good' and 'bad' hours, reducing usefulness of forecast functionality<br>• Conflicting information to that provided by with History screen, leading | • **Address the problem** with forecasting feature where most times/days are 'bad times'<br>• Make a best-case and worst-case scenario by **scaling for the specific area** that someone lives in. This will increase relevance by showing relative green times instead of absolute |

| | | | |
|---|---|---|---|
| | | to mistrust of data | green times.<br>• **Reduce** the number of days in the forecast to 2 or 3 days. Any longer is as trustworthy as a long-term weather forecast, and also not particularly useful to users. |
| General Feedback | • App was generally **easy to understand**<br>• Increased awareness of users' local energy system and generation mix | • **Lack of green times** to use energy<br>• People aren't sure how the App would benefit them | • **Notifications** to increase engagement<br>• Further information for **how to change behaviour** e.g. links to other website and sources of information on improving green habits more generally<br>• Address problems with **locating postcodes** on the App |

## Google Analytics

| | Screen Views | Average time on screen (seconds) |
|---|---|---|
| Now | 4,436 | 57 |
| Today | 1,853 | 61 |
| History | 1,212 | 50 |
| Forecast | 1,416 | 62 |

The Google Analytics Data[8] showed that the Now feature was the most used feature of the app. This is likely due to the fact that this is the default screen when people first open the

[8] Accessed April 2018

app. This is followed by Today, Forecast and History. Average time of usage was similar for the major features, with the slightly lower usage time of History corroborating with much of the online survey feedback saying it lacked relevance to users.

The Rewards event category, i.e. the ability for a user to say whether they will 'Use' or 'Move' energy, was used a total of 1,877 times with 84% saying that they wanted to 'Use' energy and 16% saying that they would 'Move' energy. This suggests that some users were interested in changing their behaviour on occasion. However, it is unclear how many of these times actually resulted in behaviour change or whether they were responses recorded by people experimenting with the functionality of the app.

| **Number of week after initial use** | week 0 | week 1 | week 2 | week 3 | week 4 | week 5 | week 6 | week 7 | week 8 | week 9 | week 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Retention rate** | 100.00% | 18.60% | 8.29% | 7.56% | 5.17% | 4.76% | 4.24% | 2.47% | 2.88% | 2.64% | 2.45% |

**Figure 27: Table showing user retention rate since app launch**

Figure 27 shows the user retention rate of the app. This shows that less than 5% of users were still using the app after a month of downloading it. This would suggest that the app in its current form does not result in prolonged usage in most cases. There are several potential reasons for this:

- The app is not engaging with users on a fundamental level. The difficulties of enacting long-term behaviour change on energy issues are well studied.
- The app may be a curiosity once it had been downloaded, but the majority of users were not using it regularly to change their behaviour. It may be the case that users do not *need* to use the app once they have learnt its key message – i.e. the link between windy and sunny weather and times of low carbon electricity.
- The app was not providing actionable information to a lot of users as there wasn't enough variation in carbon intensity in their local supply. This could be a result of:
    - Issues associated with the lack of resolution in the forecasting inputs
    - The characteristics of a BSP that has low amounts of local low-carbon electricity
    - The fact that the app was released in Winter, when supply of low carbon solar electricity is low, reducing the overall carbon intensity of supply

These points have been used to derive a set of changes and additions to the original Carbon Tracer to be implemented under the follow-on Carbon Portal Project.

## Key learnings and takeaways

### User recruitment platform

In terms of feedback gathering, it was learnt that participants of online surveys recruited through Prolific.ac can be a source of rich and varied qualitative feedback. Results of the surveys echoed the thoughts of the phone interviews: similar themes and ideas were raised from both platforms, thus further validating it as a form of feedback gathering. Although there were some respondents who 'gamed' the system by trying to answer the questions as quickly as possible (and get paid nonetheless), the vast majority of submissions were legitimate. It is possible to exclude participants who 'gamed' the system by doing a round of quality assurance on the answers and by considering how long it took for submissions to take. In this experiment it was estimated that less than 5% of answers were illegitimate, and the majority of these were removed.

### User feedback

There was generally positive feedback according to engagement and usability metrics across all features of the app. This was backed up by comments left in the qualitative part of the online surveys, as well as the telephone interviews. However, it should be noted that although the results were positive overall they were still only scored between 3 (neutral) and 4 (positive) on the Upscale, suggesting that engagement and usability were mildly positive at best. The expected 'beach-head' segment, i.e. those who had indicated interest in environmentalism and local energy, did score higher than other segments in terms of engagement across the app features, however even their responses suggest mildly positive engagement at best.

User retention was very limited, with a drop-off of about 90% of users after a month after their first use and over 95% shortly after. This would suggest that the app in its current form is not likely to be something that a large number of people use on a regular basis to change their electricity usage to times of lower carbon intensity. It is recommended that further research is done in the summer to test the app with new and old users and understand in more detail why user retention is low.

The app may have been used to 'move' energy consumption by some users, however it is unclear how reliable these results are due to the lack of evidence other than the honesty based in-app reporting done by users themselves. This is discussed further in a later section.

Users of the app had an increased awareness of their local energy system, implying that it was educational and that the content was understood. A number of suggestions were made to improve the features currently presented in the app:

- State the post-code of the user, not of the BSP, to avoid confusion and improve the perception that the app is showing relevant information to the user in the 'Choose Location' screen;
- Make the Forecast look-ahead two to three days instead of seven. This would mean less information would have to be crammed on a single screen, and there was uncertainty over the accuracy of long-term forecasts;
- Addition of notifications to engage people to use the app, in the same way that you might get a notification for a text message or email (e.g. now is time to use some energy); These notifications could be customised by the user to alert them to times they are interested in (i.e. ones that are relevant to their daily routine) and/or the next 'green' time for them;
- Add further information that could empower people to change their behaviour that can be accessed easily in-app, without having to follow a link to an external website;
- Address the lack of variability in the Forecast feature by increasing the resolution of forecasted data inputs.Add the location of renewable energy generation (e.g. where local solar power plants are) on the map;
- Integrate with smart meters/appliances so that behaviour change can be tracked and monetary and emissions savings can be quantified;
- More tailored functionality for electric vehicle owners. For example, it would be useful for owners to understand when would be best to charge their vehicle over a 24 hour period.

### User Willingness to Move Energy Use on the Basis of Carbon Intensity

In respect of user willingness to shift their energy usage on the basis of the carbon intensity forecast, we found that there were significant comments about the accuracy of the forecast and this may have driven the user view on the usefulness of this a mechanism for guiding their decisions. The forecast is based on the BMRS 2 – 14 day forward projection (from the BMRS API) for the infeed. This is too far out for the purposes of assessing behaviour change that we were looking to assess, a user of the app would generally want to postpone an activity at most for 12 hours and possibly even less. A future change may use the National Grid's own 0 – 48 hour forward forecast of carbon intensity which is not limited by the same considerations that affect the longer term BMRS forecast. This facility was not available at the time of the original development.

The findings that were obtained by using the Google Analytics mechanism (as described in the section above and shown in example below) showed that in the five months following app launch and between February and July 2018, of 479 occasions when App users clicked on the App button “I Need to Use Some Energy”, they followed up on 359 (75%) occasions that this meant “now” and on 120 (25%) occasions that they would “delay to a greener time”. This is a rather blunt analysis as it does not take into account how long it would be in each case to reach that next green time, and of course only includes the users who found and then interacted with this particular app function. Assuming that app users are likely to be among the more environmentally responsible members of the public, the percentage of the public at large would be very much less.

This contrasts also with the questionnaire results (see Figure 31) where between 33% (from the class of users categorised as fossil lovers) and 78% (passionate environmentalists) indicated a general willingness to consider moving their energy use activities (the percentages are even higher when the “not sure” answers are taken into account). The divergence in these two sets of results would tend to suggest that when faced with an actual situation (rather positing a theoretical principle) people are less willing to shift their activities due to the sheer inconvenience of doing so at that immediate time. This quick look analysis also assumes that the app was taking input from users who were indeed about to use energy.

Considering that we have some 250 active monthly users of the app, we might therefore reasonably infer that around 60 would be prepared to move their energy use on any given occasion which we could surmise as once per day. At the level of the app users this is less than one deferral per BSP per day, although approaching 25% willingness to at least engage is still very material.

To get a preliminary view on the potential energy shift that might result from customer willingness to modify their behaviour, it is possible to combine the figures on willingness to move their energy use tabulated above according to the distribution of energy “types” (See Figure 23). This indicates that while some 62% of the overall population would be willing to do so, this is likely to translate into only around 15.5% that might take action when faced with the actual decision if required to action this manually, and even this assumes that the customer is present and able therefore to take such action.

| User Type | Will Consider Move % | Percentage Of Population | Combined Population Percentage |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Passionate Environmentalist | 78% | 10.5% | 8.2% |
| Green | 65% | 47.5% | 30.9% |
| Not so Green | 66% | 27.5% | 18.2% |
| Fossil Lover | 32% | 14.5% | 4.6% |
| Total with good intentions | | 100% | 61.9% |
| Prepared to take immediate action | | 25% | 15.48% |

Considering the South Wales operating region of WPD for which housing data is currently available, this shows that there are some 1,567,931 residences. Assuming the above 15.48 percentage this would suggest that considering one event movement per day per willing household, we would have a maximum *capacity* for around 242,000 energy use deferments in South Wales alone. This requires all potentially active households to be using the Carbon Tracer app regularly and the customers available. This would clearly not be the case.

Published figures indicate that (by way of an example) an A+ rated washing machine uses some 1.36kWh of energy per ~ hour long cycle. Assuming that all the deferred events are of this type would therefore result in the conclusion that the daily potential shift is up to 330MW for South Wales, where the total of the maximum demand values across all the BSPs in our data is around 1500MW. Clearly not all deferments would take place at the same time and to the same target time slot as all the BSPs have different profiles, and this includes some where meaningfully greener slots are not always available/visible. Also as noted above, not all customers are using the app or in the right place to make the changes if these are being done manually.

As a further South Wales example, a 7kW EV home charging point serving a typical electric vehicle (30kWh) requires a charge time of a little over 4 hours. Assuming a charge every other day in a case where an ambitious level of 10% of households have an EV and again, that 15.48% of such households are willing (and in the case of an EV are able) to defer their charge, this would therefore mean that some 726 MW of deferments per day could be seen for EVs alone. It is not meaningful to compare this to current loads at the BSPs as this would have been significantly changed under such a scenario.

The situation is clearly very difficult to predict and the nature of the analysis would change radically if appliances could be automatically driven by automation, drawing on an API service to provide Carbon Intensity forecasting (removing the user from the loop).

Considerations which need to be taken into account include:

- Whether automation is available to control appliances via an API service;
- If automation is available, would customers choose carbon intensity as the controlling factor if others are available (cost);
- If automation is not available, can users set timers on their appliances to control start to within a projected green slot;

We will continue to monitor the results from the Google Analytics to further refine these numbers.

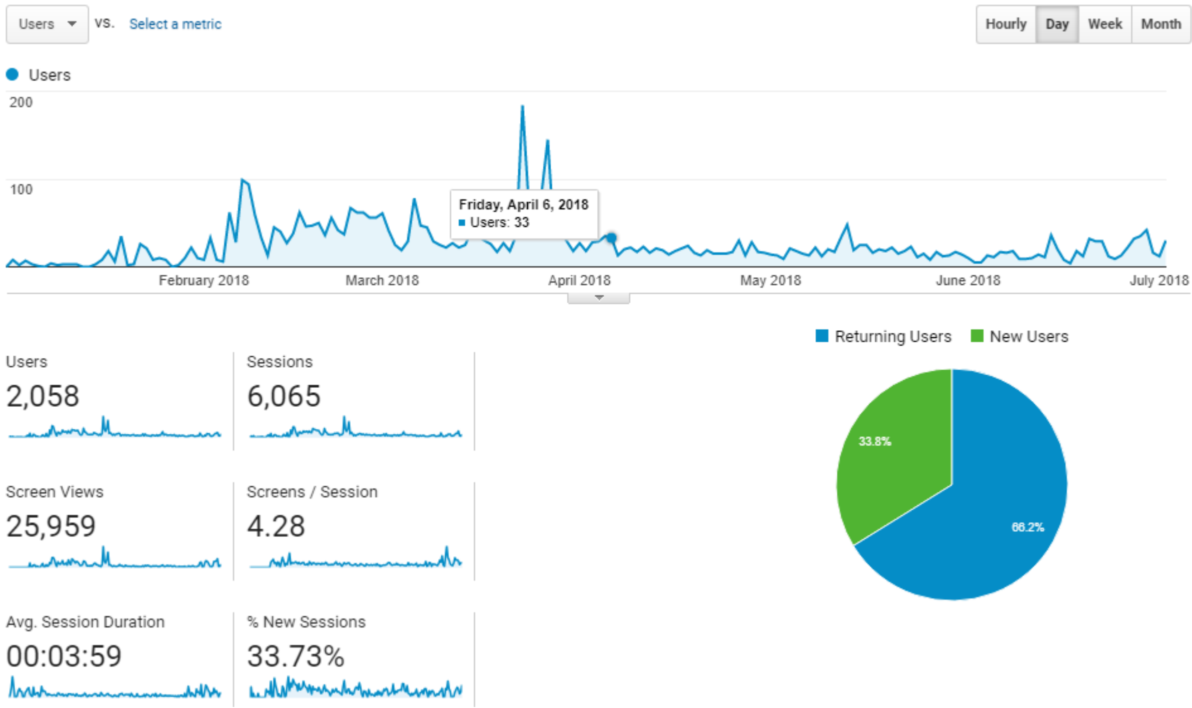
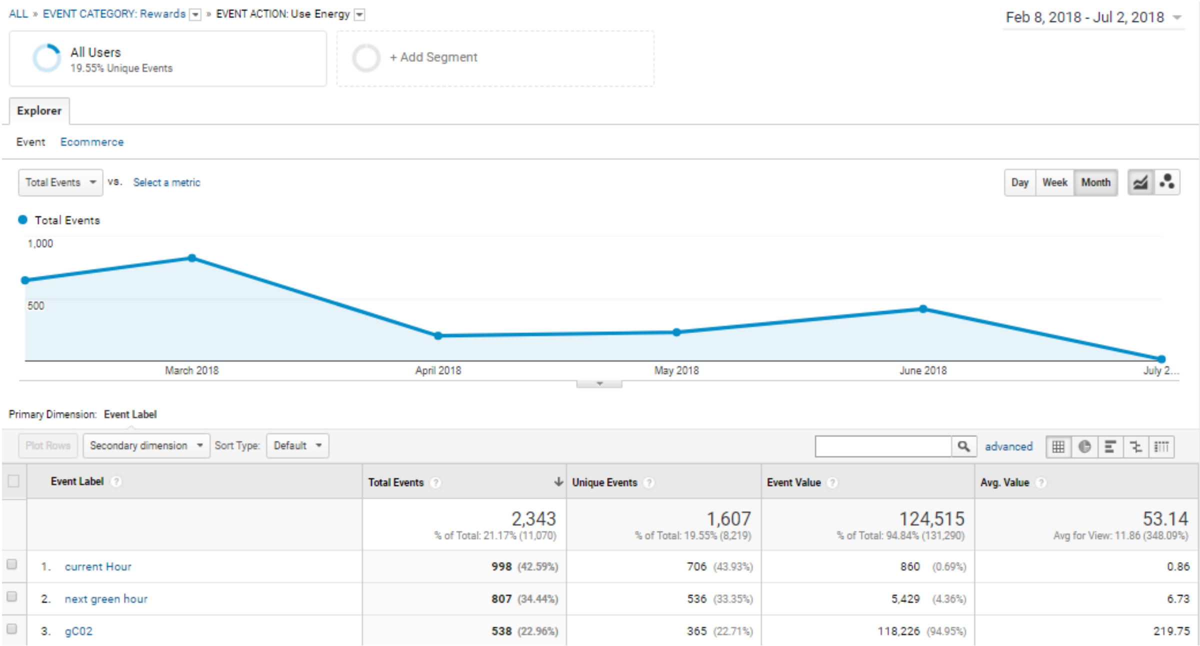
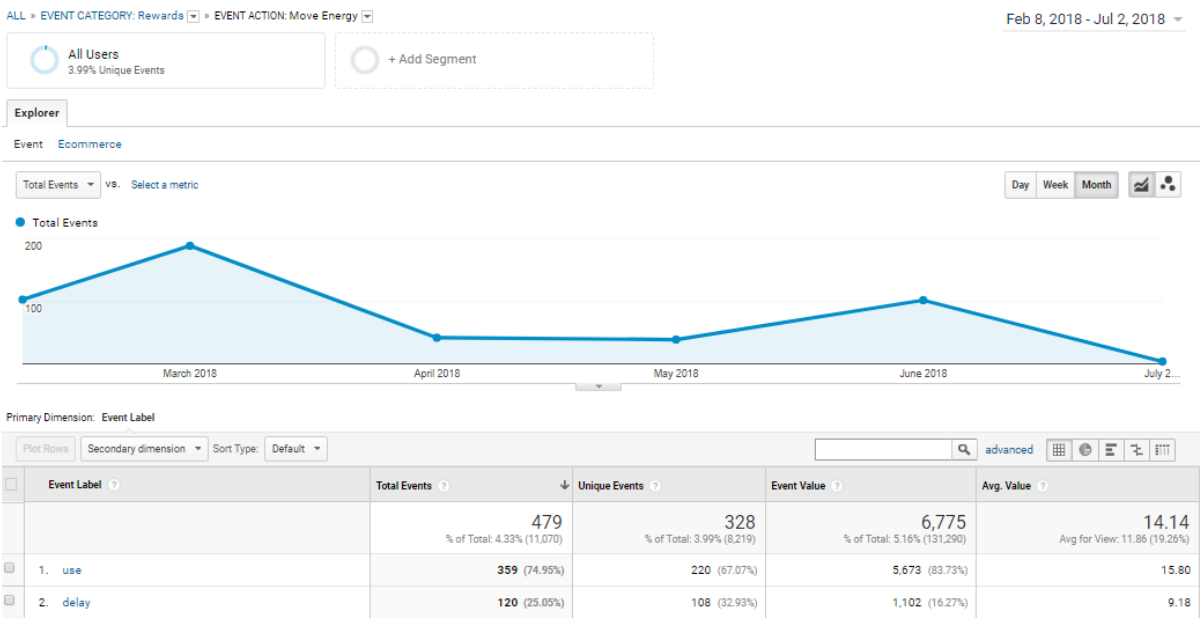



Figure 28 – Post Launch, Daily Users to July 2018




| | Event Label | Total Events | Unique Events | Event Value | Avg. Value |
|---|---|---|---|---|---|
| | | 2,343<br>% of Total: 21.17% (11,070) | 1,607<br>% of Total: 19.55% (8,219) | 124,515<br>% of Total: 94.84% (131,290) | 53.14<br>Avg for View: 11.86 (348.09%) |
| 1. | current Hour | 998 (42.59%) | 706 (43.93%) | 860 (0.69%) | 0.86 |
| 2. | next green hour | 807 (34.44%) | 536 (33.35%) | 5,429 (4.36%) | 6.73 |
| 3. | gC02 | 538 (22.96%) | 365 (22.71%) | 118,226 (94.95%) | 219.75 |

Figure 29 - Google Analytics - Events - Use Energy




| | Event Label | Total Events | Unique Events | Event Value | Avg. Value |
|---|---|---|---|---|---|
| | | 479<br>% of Total: 4.33% (11,070) | 328<br>% of Total: 3.99% (8,219) | 6,775<br>% of Total: 5.16% (131,290) | 14.14<br>Avg for View: 11.86 (19.26%) |
| 1. | use | 359 (74.95%) | 220 (67.07%) | 5,673 (83.73%) | 15.80 |
| 2. | delay | 120 (25.05%) | 108 (32.93%) | 1,102 (16.27%) | 9.18 |

Figure 30 - Google Analytics - Events - Move Energy

### Next Steps

For the future, once the Carbon Portal API[9] services become available, it then becomes possible to take the decision making and management of the shift in energy use for time movable appliance operation away from the user and into some form of home based controller (purely as an example, of the Hive type) which could switch appliances automatically according to Carbon Intensity projection.  This requires third parties to develop Apps or computer programs to call the WPD Carbon Intensity APIs and initiate the necessary hardware based actions (charge EV, turn on dishwasher etc).   In this case all that is then required is a willingness of the user to allow such control using this as the criteria, and as discussed above this is likely to enhance the sort of deferment (or more generally energy usage shift) that we would wish to see.   In such cases we would expect much higher uptake as the user is not then personally inconvenienced by the management of the task and having to remember when to do it, although there will always be the inconvenience associated with the delay in availability of the processed items (dishes, washing etc).

# 5 Performance Compared to Original Aims, Objectives and Success Criteria

The project met its objectives in deriving a design for and deploying a carbon tracing app for use by WPD customers.

The “Success Criteria” identified in the Project Set-up Documentation (Carbon Tracing Project Outline Document) stated the following:

> *5.1.1 What does success look like?*
> *Success will be a working app and website that passes some initial trials with customers and has some good feedback.*
>
> *5.1.2 How will you know if the deliverables are as per the requirements/specifications?*

[9] API services are bits of program (routines) that are written to manipulate and provide a view of our data.  To use them, a program written by someone else "CALLS" the API service routine to do its job and hence these are the callers of the API service.

*The requirements and specification will be approved by the business and tested as well as a short trial with community groups.*

These success markers have been met and therefore as initially specified, the project has been successful.

The Project PEA also stated that:

*The project will address a perception that customers are increasingly interested in how their energy is made up. We continue to see the adoption of Solar and Wind generation and as such being able to tell a customer what the mix is like at any point in time is deemed valuable. Having created an app and website we will then test with local groups before a cross WPD implementation enabling customers to see their generation mix and allow for their own generation as well.*

*Once this is available to all, we will then measure interest across the WPD area.*

*Success Criteria*

*Success will be measured within the trials and then monitored once live. We will also be monitoring how we can make the calculation more accurate over time.*

Again, according to these statements, these objectives have been achieved. The trials were truncated however, there was no live app phase-1 deployment and feedback on look and feel alone was sought to expedite this area of the design.

Users own generation has not been included as this would be quite difficult. It cannot be done from WPD held records as we are not in a position to reveal individual household details. Furthermore, the computation of the mix details and carbon intensity is dependent on knowing the extent of the demand, so the inclusion of a user's own details would require them to input their own situation (perhaps using sliders) as current generation and current demand. This could potentially be achieved in future using some sort of smart meter integration for the app.

Locating and adapting the data required to support the project proved challenging and this area may be streamlined in the future. Much of the data was bespoke, assembled from multiple sources and in some cases not readily repeatable. The biggest area of concern is the BSP data as it has to cover the 270 BSP level substations across the four WPD operating regions. By utilising the outputs of other projects, the Carbon Tracer was able to simplify the task of BSP data management by the use of template BSP "types" along with individual maximum demand values.

Several opportunities to improve the accuracy of the app have been identified and some may be followed up in future. These include:

- Using the temperature from the weather feed to adjust the BSP load profiles. This requires additional data analysis in the strategic Studies team who provided the BSP load profile template sets for the Project;
- Using the temperature from the weather feed to adjust the solar profiles by a further scaling. Solar PV response has been shown elsewhere to have a temperature dependency;
- Including some tidal information to scale tidal generation;
- Special treatment for selected BSPs which have been found to have a character dominated by particular forms of non-renewable generation (such as Cardiff Central which has a very large waste generation plant). Customers in such locations may be put off by the poor prospects for green slots, so any generator operational timetabling information might help such special cases;
- Of course, ongoing updates to the existing datasets as generation is added/changed on the network (via the generation file) and as the strategic studies teams issue new/revised datasets.

A summary of the app objectives, measures of success, and results in achieving them are shown below.

| App Objective | Measure of Success | Result |
|---|---|---|
| Provide WPD with understanding of what extent their customers are engaged by the concept of carbon intensity. | Positive user feedback on how much the information in the app engages the user | ✓ |
| | Analysis of app data to test sustained use of app | ✓ |
| | Number of app downloads and website users | ✓ |
| To help people have an improved understanding of their local energy supply | Evidence that awareness on issues related to the user's local electricity system has improved as a result of using the app | ✓ |

| | | |
|---|---|---|
| To understand whether the app, in its original form or through a future iteration, could illicit behaviour change | Positive user feedback on how much they have / are willing to change their behaviour using the app | ✓ |
| | Indirect feedback through use of Reward feature to see how often people were willing to move their energy use to 'greener' times | ✓ |

# 6 Required modifications to the planned approach during the course of the project

The project proceeded largely as expected. An initial information gathering and high level design phase was brought to a close when the then Project Manager left WPD to take up an external post. This provided the opportunity to revalidate the approach and reshape the project to ensure that a workable low level design for the app and website was in place. As the App developer had not been selected when phase 2 commenced in April 2017, this was an early priority and the Requirements Specification was developed and finalised for use in the negotiations to scope the contractual aspects.

The exact details of the supporting data sources within WPD had not been identified before the second phase commenced, so the approach taken was not actually a modification to any previously defined approach. The data has a static base in a series of characteristic templates defining the BSP set, and this is supplemented by an actual list of generation sources and their capacities arranged by BSP. This data is then "animated" using the weather feed and date/time. We consider this an optimised approach which provides the necessary details without introducing large processing overheads.

Following the project reshaping, everything proceeded to plan. It took slightly longer than expected to arrange the Apple account which would administer the App as there were pre-existing accounts in WPD and Apple restrict accounts by organisation according to their type (internal facing and customer facing). Assistance was provided in the work to get this arranged by WPD Digital Communications.

The advice of the developers was taken and the intended trials were truncated so that there was no live app phase-1 deployment, this was replaced by use of a static screen demonstrator encapsulated in the Marvel App. Feedback on look and feel alone was sought to expedite this area of the design. A short Beta test phase just prior to release involved the main stakeholders and allowed the Pen Check to proceed (see below).

WPD/IR also required a full third party security Penetration Check (Pen Check) to be carried out over and above the basic security checks done by Enigma on the host Hyve system.

Marketing activities were curtailed with respect to the level planned in phase-1 to meet the reduced budget for phase-2, extracting maximum value by using the most effective channels (Facebook, Twitter, Linked in) and delivery via WPD and Carbon Trust dedicated pages and distribution lists rather than reliance on paid-for advertising. This may have meant fewer users being gathered, but in the event, the app/website saw around 1000 initial user accesses in the first four weeks of operation.

# 7 Project Costs

The project remained within planned cost throughout, though there was a mid-project re-plan needed to adjust the scope of the project. As a largely data management and software development this was therefore not a classic WPD project structure or particular area of expertise and there has previously only been one app development in WPD (Power Cut App). Following the mid-term re-plan the project then proceeded as expected.

There was some use of contingency to develop an enhancement that exceeded the project scope but which significantly enhanced the ability of the project to gather information from users of the app in furtherance of the aim to determine to what extent users would modify their behaviour given the information made available to them within the App. Prior to the enhancement it was going to be necessary to check user questionnaires to obtain this information, however the developers suggested the use of a “game” type reward scheme which could score users according to their declared behaviour. Gamification had been identified by Carbon Trust during the early information gathering phase but with the app design now clarified, the method became clear and the enhancement provided the desired mechanism. However, it is not clear to what extent gamification could help user retention, as experts interviewed in the research phase of the project stated that it was likely to improve retention over the short term only.

Regarding benefits – these were in line with initial expectation. It has become clear that there are ways in which app development could become more automated and by which data could be sourced and made available to app developers (including third parties, i.e. to design apps not driven by WPD). A follow on project therefore becomes possible which would find ways to service this new operating capability. There are also elements of the design and implementation which can become generic knowledge/base functionality for other future projects. This includes:

- The overall App design, development, deployment and support process within WPD;
- The method of *efficiently* pegging a user/customer to the appropriate place on the network when they enter their location using the ESA polygon set (for BSPs in the Carbon Tracer – primary polygons are also now available for finer resolution applications);
- The method of scaling individual generator capacities to actual (predicted) output using sequentially layered techniques (Wind and Solar) and using fixed scalings for more complex and/or non-deterministic generators (such as CHP installations, Biomass, Hydro) etc. (See Section on *Scaling of Generation*);
- The use of data from WPD strategic studies as *substation templates* giving normalised load profiles which can then yield an actual (predicted) demand (net of generation) by scaling up with a maximum demand value.

# 8 Lessons Learnt for Future Projects

The table of learning for the project is presented below.

| Topic / Area | Learning Generated |
|---|---|
| **Analytics** | Google analytics provides a large amount of useful information regarding App and website usage. |
| **App Design / Dev** | BMRS Data feeds give usable near real-time data to provide a grid infeed breakdown to use in conjunction with scaled capacity information for locally attached generators. |
| **App Design / Dev** | It was found (this is not new information as such, but was important in the context of the Carbon Tracer project) that some BSPs are poorly provisioned |

| Topic / Area | Learning Generated |
|---|---|
| | for generation connections. This is particularly true for BSPs of the classifications Urban and Mixed. Many of these BSPs are inner city locations and consequently have a smaller area than, say, the Rural BSPs . At the latter there can be much more renewable wind and solar PV generation due to there being more room for such generation sites in the country. With the analysis in the app being done at BSP level it was therefore fund that some locations had very little potential for showing a good mix of renewables and consequently would be constrained to have high values for the carbon intensity. As the App was designed assuming that carbon intensity would be improved by good green generation conditions, this did render the app less useful in many urban type BSP locations and could therefore have meant that many potential users might be put off. We look to feedback to verify this. |
| **App Design / Dev** | Wireframing (and for App development a useful tool is called Marvel) offers a good way to rough out evaluation screens and is a cost effective alternative to a pilot development in a real app. The drawback is that the screens are static so can cause some test user disorientation, for example a NOW screen in the Carbon Tracer app was actually a screen capture with an August date, so when looked at later appeared to be historical. |
| **App Design / Dev** | The app needs to work on 2 levels, the local picture and the national picture. Local demand is met by local generation to the extent that it can be and then the gap between current demand and current generation is assumed met by grid infeed. |
| **App Design / Dev** | Grid infeed details are available from the BMRS data feed which has an online API. |
| **App Design / Dev** | Some large generators (power stations) are attached to the 132 side at some BSPs and appear as connected to these BSPs. Such connections would dominate the mix/breakdown at these BSPs and so have to be discounted. |
| **App Design / Dev** | Solar generation requires scaling back from the declared capacity to derive an instantaneous solar generation value by two main factors which are applied in this order:<br><br>1. The position of the current date/time in the diurnal response curve for the day in the year. A response curve should be available per day and at a range of latitudes spanning the latitude range of the WPD operating area.<br>2. The day response value needs to be scaled according to the prevailing weather conditions, as cloud cover and to a lesser degree precipitation. The temperature dependency of PV panels is not |

| Topic / Area | Learning Generated |
|---|---|
| | currently being modelled and neither was there any information relating to the PV response when panels are covered by snow. |
| **App Design / Dev** | When determining the solar response and fixing the current time in the overall day response curve (to index into the curve and obtain the correct response value), it is necessary to use the local time (of the BSP) not civil time. Local time depends on two main factors: the users longitude E or W of Greenwich and on the equation of time for the current date. Both factors act to mean that the local time and civil time can be as far apart as around 40 minutes.<br><br>The project had access to some empirical PV response data taken from site based measurements across a number of locations. This data was NOT corrected for the above factors or GMT and showed a clearly skewed response curve when compared to the modelled responses. |
| **App Design / Dev** | Wind generation requires scaling back from the declared capacity to derive an instantaneous wind generation value by finding where on the wind response curve the current wind speed is located. A response curve is used for a typical turbine (as the turbine type is not known anyway and there will likely be a range of these). |
| **App Design / Dev** | There are weather data feeds that can be used by the app (and website) to obtain the necessary parameters to allow for solar and wind scaling to be carried out. The one used in the app is "Dark Skies". |
| **App Design / Dev** | It is not currently feasible to scale other generation types back from declared capacity as the conditions for these cannot (in most cases) be easily modelled. As a result, the project used some empirical generation scaling values determined by another project. Some cases may be handled in the future however. E.g. on times for Stor generators may be temperature dependent. |
| **App Design / Dev** | Choice of app support framework.<br><br>Ionic was chosen as a technology framework for the front-end, because it allowed efficient duplication of the application code for two different platforms – effectively almost halving the estimated cost of developing separate Apple and Android applications. This proved to be an important time-saving decision.<br><br>A key learning from the development of the front-end was that when developing across multiple platforms (e.g. different browsers, phone |

| Topic / Area | Learning Generated |
|---|---|
| | platforms, devices), at least 35% of the project's total elapsed time will be spent on testing and correcting differences between these platforms. |
| **App Design / Dev** | There are a number of approximations and generalisations applied in the app which mean that the analysis it conducts is necessarily approximate. A separate analysis has been carried out on this. |
| **App Design / Dev** | The app could be made to operate even more locally at the Primary level, as attached generation and ESA polygons are available at this level. However the amount of data, including data that would need to be specifically tracked down, would be high with 1800 primary VS 270 BSP substations. |
| **App Design / Dev (Reusability)** | The ESA polygons (from another project), and the mechanism for locating a user on the network using these, could become a standard piece of library functionality for other apps/website facilities. |
| **App Design / Dev** | The app could be made to incorporate the effect of temperature on demand as the PSD Ben Godfrey Project has data for the demand curves with upper and lower bounds as well as mean (which was used). A future version of the app could use the temperature from the weather feed to set a demand value between the upper and lower bounds with the amount of divergence from the mean determined by the temperature.<br><br>The demand curves are also not defined by day of the week but solely by season and BSP type. Thus there is no differentiation of weekend response from weekday.<br><br>The cut-over between seasons is also fixed with, for example, the spring demand curves being used from March 1 to May 31. This proved slightly unfortunate in 2018 when the weather attained its coldest interval for several years around March 1sts. This would be more difficult to change, requiring linkage to the weather feed to make this cutover more dynamic. |
| **Data** | Aggregating the generation data for the sites across the whole of the WPD regions it is clear that solar (at 3.5GW) is over twice the amount of generation as the next most common form "Other" (at 1.5GW). There is just under 1GW of Onshore wind. The only other appreciable totals are for "mixed" and "landfill, sewerage gas" both under 500MW. |
| **Data** | A more automated mechanism for deriving the driving data for the app is required. There is a high dependency on the ongoing work of other BAU and innovation projects and much bespoking of the overall dataset. Preparation of data for use in the app took a considerable amount of time and effort and it was fortunate that the sources used were actually available when they were needed. |

| Topic / Area | Learning Generated |
|---|---|
| **Data** | While the derivation of BSP details (for maximum load) is straightforward in many cases, there are a few more complex locations across the WPD network. For example:<br><br>• Grange BSP in South Wales is a largely industrial substation but it also supplies settlements in the Llynfi valley. This required the load to be determined from the lower level primaries rather than at the BSP level;<br>• Buxton BSP is fed by ENW so there is no load information available;<br>• Yeovil BSP has shared busbars with another DNO;<br><br>It was also noted that while many of the ESA polygons reflect simple supply areas (of various shapes and sizes) bounded by a single outline, this is not always the case. A customer reported, in feedback, that their postcode reported in the app that it was not in the DNO coverage area while this should clearly have been a WPD supply. As a result the app was not functional. On investigation it was found that the user should have been under Hall Green BSP but actually lived in an island supplied by this BSP contained inside the outline of another BSP ESA polygon (Solihull). An adjustment was made to the app to repair this bug (based on a lack of checking for this possibility). |
| **Data Integrity** | The app was targeted at the BSP level. Not only is this a sensible point for aggregation of sufficient generation to allow for a more meaningful analysis, there is a set of supply area polygons covering most BSPs in the 4 WPD operating areas. The area polygons have been determined on another WPD project and there is also a level of demand analysis available for each along with an assessment of BSP type. This allows for the derivation within the app of a set of demand/load curves for Each BSP, by season and type. In consequence, the app can therefore determine the instantaneous real load (which along with the available instantaneous generation allows the grid infeed to also be determined).<br><br>BSP level is a suitable level at which to provide local information as there is sufficient data on the BSPs and the overall amount is not overwhelming (270 BSPs as opposed to over 1800 primaries). The amount of locally attached generation was also usually sufficient to provide an appropriate breakdown and amount of interesting information for the App, however as described above, this is not always the case. |
| **Data Integrity and Visualisation** | It was found that the BMRS forecast was on the pessimistic side in terms of its view of the renewable components. This meant, especially at BSPs with |

| Topic / Area | Learning Generated |
|---|---|
| | a large NG infeed due to low generation levels (some of which were always in such a condition due to reasons detailed elsewhere) that the carbon intensity of the mix was regularly high (in the forecast) and fell wholly inside the red colourised banding. Where this mix was slowly changing this made for a very visually uninteresting forecast which was, as a result, unusable (without clicking on the individual hour strips) for its intended purpose of finding a suitable interval in which to carry out high energy use actions.<br><br>It was therefore determined that a suitable approach to rectifying this would be to expand the number of colours used from simple Red/Amber/Green to more levels with different shades of red and green. |
| **Design/Data** | WPD attached generation capacities are available per site from a Crown report which is used to provide the export file WPD-GEN-INFO.TXT. The information is currently available, provided for the site but not the level (132/11 etc.) at that site. |
| **Design/Users** | On the advice of Carbon Trust regarding reduction in complexity within the app and the presentation of a clear message, the app was structured in a simplified way. This meant the avoidance of engineering units (percentages preferred) at the top level and concentration on the carbon message, although it was also determined that interested users should also be able to drill down to such engineering information where this was warranted. A separate report presents learning from user engagement. |
| **Go-Live** | The App go live was initially scheduled for January 8th 2018, though this was delayed due to App Store issues (particularly with Apple). This was badly considered in one sense given that the largest national green generation source is Solar PV which is comparatively at very low levels in winter. As a result some of the screens were much less interesting than we had expected. When the App finally went live in early February, there was an improved solar PV output and by the end of February the screens were looking more visually attractive. |
| **Go-Live** | Notify the customer contact call centre prior to go-live with any public facing function. This was done for the Carbon Tracer and the call centre appreciated being involved. Such an approach is much better than having a customer ring in and the customer contact call centre have no knowledge of the situation. The PM was given as contact for queries (which were not expected to be numerous). |
| **Licencing** | WPD is entitled (as a signatory) to use the BMRS facilities without charge.<br><br>As the app was free to use, several other facilities were also free to deploy in |

| Topic / Area | Learning Generated |
|---|---|
| | support of the App. This included the solar profiles (SOLRAD tool) and the UKHO alamac data. Most sources require crediting with their details as part of their terms so this should be checked and implemented as required. |
| **Marketing** | The largest new user pickup was following the launch when Carbon Trust and WPD both carried out marketing activities. Addition of new users was sustained at a level of 22-25 per day through periods of active marketing of the App and website |
| **Marketing** | The narrative on the App stores should be very clear and state immediately the geographical area in which the App operates. While this was stated, it could have been clearer as a number of users in clearly inapplicable locations downloaded the app and then (from analytics) failed to run it for any serious amount time, for obvious reasons. Users were seen in such locations as USA, Turkey, Japan, India, Europe (various), UAE. Some UK users out of area may have been valid WPD users away from home. |
| **Operations** | A 3 day/month support contract with the App developer provided a useful level of support time to keep the app maintained and operational as well as conducting a low level of small adjustments. |
| **Operations** | A BAU owner for the App would be a better option than attempting to run this only temporarily as an NIA project deliverable. NIA/innovation is not geared up to operational use. |
| **Operations** | There is evidence that a limited number of users are prepared to shift their energy usage on the basis of Carbon intensity level forecast. This was difficult to assess in detail for 2 reasons: the user numbers engaging with the gamified awards mechanism was low and the current forecast mechanism was limited in its capabilities. |
| **Project Mgmt** | Publicise the project amongst peers to ensure that cross-project cooperation can take place to ease the project tasks or enhance capability by cross pollination. This worked particularly well with the Network Strategic Studies project which provided ESA polygons, generation scaling data and normalised load data at the BSP level. This allowed a potentially massive data requirement to be simplified by using BSP classifications (Urban, Rural, Mixed and Mid-day Peaking) and scaled characteristic load profiles in conjunction with individual BSP peak demand information to generate a load profile for each BSP. |
| **Security/GDPR** | The legal department were asked to check the GDPR requirements (new legislation from May 2018) of the project and confirmed that no personal data was being used. This simplified the approach to data management, all of which is aggregated anonymous BSP/network level. All projects should |

| Topic / Area | Learning Generated |
|---|---|
| | check their obligations in terms of GDPR even if the outcome is that these are not present or minimal. |
| **Security – Hacking & Penetration.** | WPD Information Resources (IR) were involved at an early stage to advise on all relevant aspects of the project and were kept informed of developments. IR required the carrying out of third party penetration tests to verify the system and minor issues were identified (these are not stated in this report). |
| **Source Networks** | Some BSP feeder arrangements are complex especially involving 66kV in the W Midlands where there are also feeder loops. There are also in S Wales some customers fed from largely industrial BSPs, for example the Llynfi valley is fed from Grange BSP which is part of the Port Talbot steel supply area. |
| **Source Networks** | The supply area polygons prepared by the PSD team (under Ben Godfrey) are available as graphics overlays and have been associated with a network reference ID. However in some cases the network reference ID is zero. This seems to be where the area is at least partially fed from another DNO, such as Buxton (fed by ENW). There are a number of edge cases like this (for example at Yeovil there are shared busbars with another DNO. |

Further detail is provided below.

## 8.1 App Design

### Data Optimisation

The approach was taken to use "animated" static data to drive the Carbon Tracer computation engine. The only alternative to such an approach would be unrealistic, namely taking the real-time analogue data for load at the substations and aggregating the output on the analogues for the various generation sites. Such an approach would not only be overkill for an app, it would take a significant amount of processing and therefore almost certainly cause considerable delay for the app when responding to users. This would also, while more accurate on a given day, require integration that is not possible between systems at the present time, namely the control system inside WPDs firewall boundary and the app hosting system which is deployed on a commercial host system. There is no present possibility of being able to send data from the former to the latter systems.

The static data is "animated" by finding demand and generation at the required time, scaling this according to the prevailing conditions (including time of day and day in year as well as the weather) and determining the grid infeed required to make up the local generation deficiency (measured against demand). The "static" datasets could thus be exported to the developer in a one-off operation and then loaded in advance onto the host system for real-time animation. Some of the "animation" can also take place on the server rather than inside the app to further optimise performance.

One area where an approach was taken to limit accuracy in favour of speed of execution (and amount of data being transferred) was in the Polygon outlines for the BSP supply areas. These polygons are available in some detail and show the outline of the normal feeder extents for a given BSP (having been derived and prepared by another project). This detail was thought to be of interest to the users, helping to fulfil one of the project objectives to educate customers in how their supply actually works. The ESA polygons are defined by several hundred points (they are also quite varied in terms of size with rural ESAs usually being much larger than ESAs covering city districts) so that to render the display of these on a mobile in an efficient way meant sending and then rendering only a limited number of points. This was achieved by the developer using an *outer hull* representation of the polygon to substantially reduce the point count. The trade-off here being that this did lead to some inaccuracy in the representation of the ESA's which would sometimes take in some sea or perhaps part of a neighbouring ESA which when itself shown would also cross over into the neighbouring area. This was determined to be a reasonable approach in trading-off accuracy against speed of performance.

### Features

At the outset the screen design had largely envisaged a relatively simple static screen showing the carbon intensity, perhaps as traffic lights or some similar representation to reflect the carbon intensity. An initial breakthrough came when the design was informally peer reviewed inside the WPD Future Networks Team and the suggestion made to include a historical display. This would require retention of previously computed values PER BSP but was entirely manageable at this level. Once the developers had been engaged and an design meetings held with all parties present (WPD, Carbon Trust, Enigma Interactive) the further suggestion was made to also include a more detailed "Today" view and a Forecast. This felt instinctively correct as an overall structure for the app, especially as it was immediately realised that a "Forecast" facilitated the meeting of another project objective to engage users with carbon intensity. No longer were they just being advised of this, a forecast then allowed for a better time to be identified for high demand activities which could therefore be postponed until the energy mix was more favourable. It even became feasible to trace whether users would engage with this sort of capability by directing them through traceable screens, with the obvious mechanism to use being that of a Reward Scheme. Many apps incentivise use by giving users merits for certain behaviours (gamification) and while a number of these were assessed, the approach taken was a sober "level-up/down" scoring system. It thus became possible for the project to assess user engagement via a more complete built in capability measuring more than just numbers of downloads, screens loaded or by external methods such as marketing interviews and App Store feedback and/or star ratings. The main lesson here is that when designing a customer facing app that electrical engineers are better advised by app designers and other interested parties (such as Carbon Trust) who have had extended customer exposure. "brainstorming" sessions do work very well in such situations.

User navigation to the location of interest was done using Google Maps, though also including a post code lookup capability and GPS position (if location service agreed to by the user in settings). The postcode(s) entered would also be locally retained so that the user might maintain a list of regular locations of interest. This allowed for rapid selection of, and change of, location. The ESA polygons for the BSPs were then used to allow the Google Maps API to find the applicable polygon and so fix the user to their BSP/supply area. This functionality is entirely reusable and now that Primary ESA polygons are available, the user can be reliably fixed to the network at this level also. The main lesson here is one of simplicity in design and optimisation of both data usage and screen flow. Users have experience of so many apps now that there are certain expected behaviours and levels of service to be provided by these and that intuitive use led by expected usage norms can be expected to provide a clear route to customer acceptance (this would be looked for in the user feedback).

Screens were made educational where possible, for example the BSP screen gave a small amount of information about the local BSP to assist understanding some of the information delivered by the app. For example while it is clear to the designers that a BSP classified as Urban is less likely to have renewables available than a large rural BSP, this is not necessarily going to be clear to the customers. This meant introducing the concept of the BSP classification (a data concept not an engineering one) as Urban, Rural, Mixed or Mid-day Peaking. This helped to meet the educational objective of the project. The lesson in this is to have an eye on the objectives when designing the app so that every opportunity is taken to meet the various objectives even tangentially on occasions.

FAQs were chosen as the "Help" mechanism and some 12 were available at the time of launch. More were added as the opportunity presented as the requirement emerged and a news "blog" was also added to make the App/Website more current and engaging to interested users.

The project realised, once operational, that the forecast was showing a very flat and often universally red (poor carbon intensity figure) – especially when compared with the History screens. Following investigation, the reasons for this became clear. The principle cause was the nature of the BMRS forecast which was given "per day" without any finer intra-day granularity. This forecast also erred on the side of assuming the presence of more fossil fuels in the mix (the BMRS report set includes separate shorter term reports for renewable source generators). Coupled with that, the low amounts of solar present in winter, when the app went live, meant that there was very little local generation in most cases to pull down the headline figure from the BMRS. To improve the differentiation in the displays it was suggested that a future iteration of the app could introduce additional colour bandings (sub-bandings) to the display of the carbon intensity so that the user would have additional visual cues for assessing the best time for the mix. Another option could be to integrate the National Grid's recently released Carbon Intensity API, that provides a highly granular and relatively accurate carbon intensity forecast. However, the limitations of this API is that the fuel mix is not-known, only the overall carbon intensity figure.

### Future Features/Extensions

There were several points in the design and development process when it became necessary to make a choice about what to develop and what to put off for possible future enhancement work. This is clearly advantageous as a clear upgrade and enhancement path for an app is very good to have, even if these items cannot ultimately be done for whatever reason. Some of the possible extensions include:

- Multiple colours in each of the bands – red, amber, green to give better differentiation in the forecast screen in particular (where the BMRS drives a more pessimistic view of the mix). This was considered a priority as the often very flat red forecast picture did not lend itself well to the intended use of guiding the customers to better time slots;
- Enhanced view of the solar and wind scaling drivers – so a "solar response today" curve to be displayed, and a "where we are on the wind response curve" to be shown so that these values do not just get presented as black box. The user could click on the sun or wind icons, where present, to get this information;
- More BSP data presentation in the opening screens.

## 8.2 User Interaction and Feedback

### Segmentation

The smart energy transition and particularly the Distribution System Operator (DSO) evolution means that understanding the customer is becoming central to DNO operation. This is primarily driven by technology development enabling consumers to become more active on the network rather than being passive "receivers" of electricity. Consumers' evolving lifestyle and habits will have a significant bearing on the size and type of network that will be required and how it will be paid for and maintained in the future.

It is also crucial for the integration of low carbon technologies into networks as domestic customers are increasingly engaging with more sophisticated business models with third parties for energy storage, electric vehicles, micro-generation and energy management, delivery and trading. Satisfying these complex and often uncertain evolving customer needs (and their impact on networks) and balancing this against the imperative to keep networks secure and recover costs will be a key challenge for DNOs going forward.

The evolution in customers' activities and adoption of new technologies will result in the changing of demand profiles. Being able to understand which customers will adopt which behaviours or technologies is therefore key to understanding how demand profiles could change in the future at the household level.

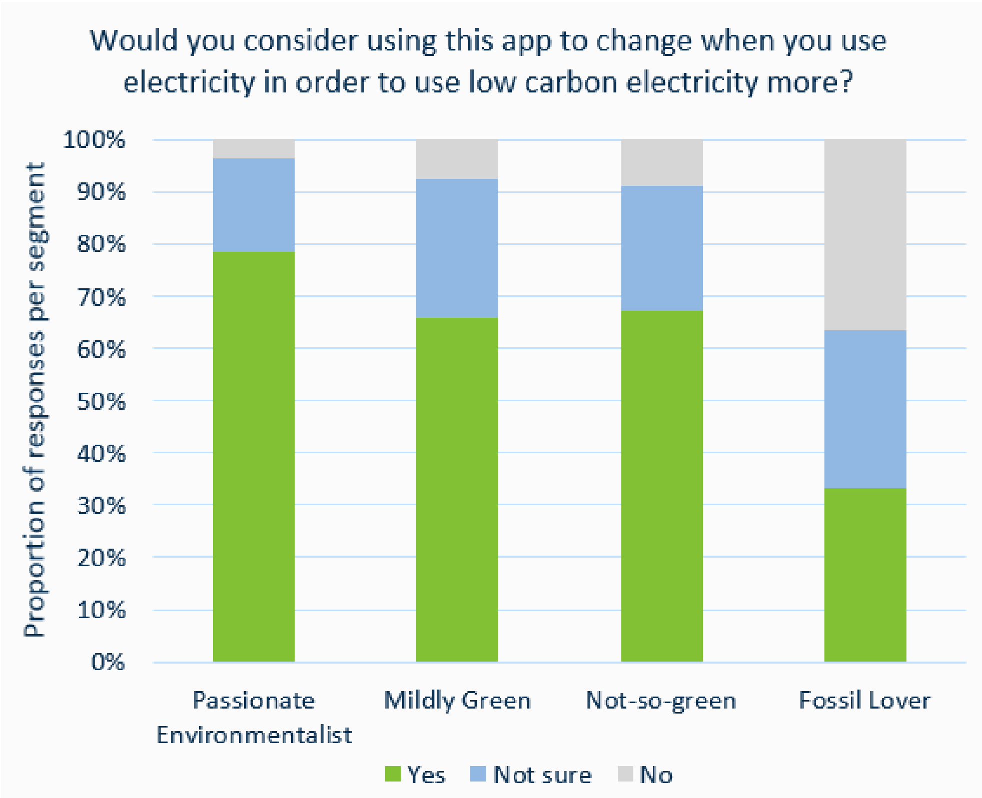



**Figure 31: Responses to the questions "would you consider using this app to change when you use electricity in order to use low carbon electricity more?" according to each segment based on environmental attitudes**

The simple segmentation constructed in Figure 31 imply that segmentation could be in used in the future to identify customers who would be willing to engage in a form of demand side response based on carbon intensity. While this result on its own is not conclusive, it suggests that further study should focus on identifying customer segments relevant to DNOs.

Customer segmentation is used to inform customer engagement strategies across industries, including the energy industry. Previous segmentations have focussed on consumers' attitudes and behaviours to domestic heating, energy efficiency product uptake and likelihood to change energy supplier. However, as-yet there has been no segmentation-based analysis to understand consumers' attitudes and behaviours related to aspects of the near-future energy system. This could be a key step in being able to forecast future demand profiles. Once consumer segments have been constructed, DNOs can start strategising on how best to plan to respond to such changes, whether it be through network reinforcement or the development of commercial mechanisms to incentivise flexibility.

### Wireframing and Prototyping

During the project development phase an early wire frame mock-up of a number of expected app screens (static images) were created and strung together by Enigma using Marvel software. This can be used on handsets (phones, iPads etc.) and has the general appearance and navigation capabilities of an actual app. This allowed useful feedback to be gathered from test users and this could be done much earlier in the programme than might otherwise have been possible, providing also insights for the development team themselves. Two main sorts of user interaction were identified:

- Review and feedback from expert users, including project and company stakeholders;
- Review by customers/general users of the app.

While very useful overall, there are some limitations to Marvel, including:

- Not all usual app navigation and links are enabled as this requires significant potential pathways to be anticipated and static images to be provided in support. This causes some minor potential for user disorientation or adverse review comments. In fact marvel offers a feature where selecting anywhere on the screen shows the active features in blue, so the users just need to be warned of the limitations;
- Again, regarding disorientation of the users – with static screens and an app which is providing NOW, TODAY, FORECAST and HISTORY, it can look odd that, for example, when reviewed in October that the forecast is for August. Or that NOW is 15:36 when this is being checked at 10:30am. Again it is necessary to make this aspect very clear to reviewers.

When assessing Marvel (and later real app) feedback, there are often contradictory indications given by different users. A sufficient sample size is necessary for public type reviewing and to this end, Carbon Trust identified a number of different ways to do this sort of reviewing:

- Carbon Trust maintain or have access to several lists of interested parties and were able to contact these groups to get feedback from sample users (albeit those with a pre-existing interest in the area);
- Recruit people through Prolific.ac where sample users who make themselves available for a small fee are given the app and asked about it.

Later in the project stakeholder/expert user review was shifted to real versions of the apps but deployed to and supported by Beta test environments, or operational environments with special whitelisted access.

### Online trial

In terms of recruiting participants for a trial, it was shown that Prolific can be a cost-effective and flexible tool. Although a small percentage of participants who 'gamed' the trial, on the whole participants provided high quality feedback with 118 of the 249 participants providing some form of qualitative written feedback.

It cost roughly £5/participant to successfully recruit a participant for the trial. This figure cav be reduced significantly by reducing the rates provided to participants for taking part in the survey (current set at £8.75/hr, but the minimum is £5.00/hr), however it felt that a higher 'wage' would incentivise more 'rich' qualitative feedback from participants. Furthermore, participants who provide high quality feedback can be selected for future trials without having to go through an additional recruitment stage, thus bringing down costs and increasing the overall quality of feedback at the same time.

Employing the UPscale was shown to be useful tool for testing consumer feedback on engagement and usability. It provided results that corroborated with qualitative feedback, and works when comparing features to each other or with A-B testing.

## 8.3 App Development

Given its innovative nature, the approach to development for the app (and shadow website) was to set up the requirements as a guiding framework rather than as a strict specification. The main technical engineering design framework was also specified as completely as possible early on so that the data might be sought from within the organisation, adapting the design where constraints with data availability would require it. The main functions, as outlined elsewhere, consisted of determining, for the chosen location, the instantaneous load, amount of generation and thus the deficiency required to be met by the National Grid infeed an then converting the amount of power from each of the component generation types into a carbon intensity figure using accepted tables of these values. Everything else nucleated around these main "core" functions. The project also took a view on trading off between performance and accuracy and also cost at certain points and several possible functional elements were omitted due to lack of budget.

The development of website and applications remained on-track for the majority of the project, facilitated by the fact that all the required resources were in place at the start of the project.

The user research, designs and extensive research into the source of the data had been completed and was ready when the development commenced, meaning that it was easy to define a project structure and stick to it / adjust when optimal as it progressed. Initially a scope was identified which was estimated to be achievable within the time and budget constraints of the project, and this high level scope was not changed during development.

The development split into two separate streams at the beginning: a 'front-end' development that created the interface and style of a website, Android app and Apple app, and a 'back-end' development which retrieved and processed the data required to calculate the carbon intensity. By keeping these separate, they could be tested in isolation before being connected, and the development team could be divided to work on each without any code conflicts.

Ionic was chosen as a technology framework for the front-end, because it allowed efficient duplication of the application code for two different platforms – effectively almost halving the estimated cost of developing separate Apple and Android applications. This proved to be an important time-saving decision, without which the development team would probably not have achieved all the requirements in the project or in the scope. A key learning from the development of the front-end was that when developing across multiple platforms (e.g. different browsers, phone platforms, devices), at least 35% of the project's total elapsed time will be spent on testing and correcting differences between these platforms.

On the back-end, Enigma Interactive's in-house 'Core System' Content Management System was used for the website and for the management and administration of the data. The team's familiarity with the system allowed it's functionality to be stripped back to the requirements of the Carbon Tracer (e.g. removing ecommerce options) more easily than using another 'off the shelf' CMS such as Magento or Kentico. The database was designed based on how the data would be supplied to the front-end – prioritising performance optimisation strategies that would limit repeat processing of the data.

In order to add a ceiling to the amount of calls that the application makes to the APIs supplying data (e.g. BMRS, Dark Sky Weather), calls are made to calculate the current and forecast carbon intensity for each BSP on an hourly basis – meaning that this call rate is unaffected by customer usage.

## 8.4 Data Sourcing and Management

The Network Reference ID (data object: NETWORK_REFERENCE_ID) is a suitable prime reference key by which the various elements of the data can be referred to the correct data objects. This value is already in use in a number of data sets and is originated from CROWN as described below.

NETWORK_REFERENCE_ID is a unique ID for a network reference, which could be a substation, feeder, feeder section, at most voltages. Network references are even available for tower lines and tower circuits. Generally though it relates to the Electricity Network Structure.

The NETWORK_REFERENCE_ID is automatically generated from a sequence, when a new network reference is created. The creation of network references is done in CROWN, usually by Control through the Network Reference icon. It's not displayed through the CROWN application at all. The users purely use the Network Reference and Network Reference Type.

The source of the weather data was undecided at the beginning of development, so a few options were considered for accuracy, support, SLAs and data detail. Dark Sky weather API is a paid service, but its cost per call is very low and it supplied a more granular level of detail in both weather data and the number of unique locations returned within the WPD service area than the Met Office weather API, which was another top choice.

## 8.5 Testing

The testing aspect of project implementation is well known, though much of this was new for WPD as the Carbon Tracer was only the second App which has been developed. The main lesson here is to be very clear about what the developer will do and what WPD needs to do.

It was considered better to do extensive validation for the driving data as this was assembled, taking this data mainly from already verified sources (business systems and other projects). This and the overall design were the main technical contribution to the project of WPD. The developers will test screen flows, GUI, gross functionality but are likely to stop short of full validation testing as they are unlikely to have the level of engineering understanding necessary to achieve this. In view of this, a specific interval of validation testing were carried out by WPD with the developer in situ at the factory. This testing was effectively a combination of system, factory and acceptance testing and in support of this, a tool was developed which could attempt to replicate the results generated by the app using broadly the same data and live driving data feeds (these had to be hard wired in as values, as establishment of real-time connectivity of a test harness to live data feeds would be expensive and achieve very little).

This approach worked very well and a number of issues were flushed out at this stage. A good correspondence was achieved between the harness and the actual app (in its test environment). The App database was queried directly to obtain necessary intermediate values for inspection, and it would be valuable in future if this route in to getting validation values could be improved beyond the use of direct SQL queries, which are slow.

The validation tool was also used post launch to continue to check the app values and ascertain why certain behaviours were seen. This approach gave valuable insights.

The test results also revealed that the generation values were very low. This was a real effect as the testing was being done in early – mid December when solar output is very low. It was unfortunate that launch would be at such a time when generation is generally not very good.

## 8.6 Marketing

Facebook was chosen as the key marketing tool as it promised a flexible and a cost-effective way of testing which audiences responded well to marketing of the app. The Facebook campaigns resulted in a reach of over 250,000 people across WPD's distribution area within a two-week focused campaign period for a cost of £3700. This was seen as being very high impacts considering the small sum and timeframe involved.

Broad targeting on social media is usually more cost effective than niche targeting, so it is unsurprising that when the audience size was expanded in the second week the ad spend became more efficient. This, however, is often at the cost of quality, which is why it was decided to go with a niche set at the start of the campaign. Broadening out the audience in this instance helped to drive more traffic to the landing page and maintain the level of app downloads during the period.

## 8.7 Operations

The app has proved to be very low maintenance in terms of operational aspects. The backend simply executes on the Hyve servers which are to a high availability SLA of over 99% uptime. Hyve is a hosting provider that Enigma Interactive have worked extensively with and have a number of applications hosted upon, meaning there are no unknowns about reliability.

There were two servers deployed in the final configuration for the App hosting/support function:

- Low specification dev/test/UAT server;
    - 1 x Server Unit [SU]* of hosting capacity including
    - Up to 5GB webspace
    - Up to 50GB data transfer per month
    - Up to 4,000 outbound emails
    - Hardware firewall
    - 24/7 proactive website monitoring
    - Daily on-site AND offsite back-ups
    - Named point of contact at Enigma

- High specification operational server.
    - 1 x Tier 2 server of hosting capacity including
    - 2 CPUs
    - 6GB RAM
    - Up to 50GB webspace
    - Up to 500GB data transfer per month
    - Up to 40,000 outbound emails
    - Hardware firewall
    - 24/7 proactive website monitoring
    - Daily on-site AND offsite back-ups
    - Named point of contact at Enigma

The most appropriate configuration was determined by Enigma within the set of possible hosting tiers available under their terms with Hyve. This was achieved by testing on a lower spec unit and expanding into the higher domain only where this was considered to be necessary.

The data feeds are similarly high availability and the only other update is the occasional manual load of a new attached generation capacity details file.

## 8.8 Future iterations / next steps

There are several ways the project can be taken forward, which are highlighted below:

**Scale-up**: The app has been tested at a relatively small scale and would benefit from larger user testing within/beyond WPD area with some feature modifications and objective clarification around specific behavioural change outcomes.

**Simplify**: User feedback suggests further simplification could drive increased engagement. Development and testing a simplified version would benefit wider learnings to other platforms such as WPD's Power Cut app.

**Improve**: The Forecast feature caused a bad response from participants as a result of the lack of resolution of the BMRS forecast data. However, the National Grid's Carbon Intensity API could be integrated into the app to show more realistic and more useful carbon intensity forecasts over a 2-3 day period.

**Evolve**: Early testing has suggested that the app by itself does not drive long term engagement and behavioural change. However, the underlying data access, interface, and user testing method has been established to be working which provides an opportunity to evolve the application cost-effectively to serve broader objectives linked to DSO transition such as DSR, EV roll out support, local systems planning support etc.

## 9 The Outcomes of the Project

The project successfully delivered the app in multiple forms (for Apple and Android) and as a website to back up the apps and/or provide larger screen capability for those either requiring this or with a preference to use a computer. The App worked as intended and the design objectives were all met. In these respects the main objectives of the project were achieved, with the availability of the utility being notified by press release, social media and Carbon Trust mailing lists on 8th February 2018 (it was live earlier for validation and further test and inspection by those signing off).

The Key Outputs & Milestones that were identified in the Project Set-up Documentation included the following items:

- Requirements Specification and Tender Documentation;
- Test Strategy and Scripts (production of these being a milestone);
- Implementation Plan;
- Final Report (including user response report).

With the completion of this report, all will have been delivered.

The project realised, once operational, that the forecast was showing a very flat and often universally red (poor carbon intensity figure) – especially when compared with the History screens. Following investigation, the reasons for this became clear. The principle cause was the nature of the BMRS forecast which was given "per day" without any finer intra-day granularity. This forecast also erred on the side of assuming the presence of more fossil fuels in the mix (the BMRS report set includes separate shorter term reports for renewable source generators). Coupled with that, the low amounts of solar present in winter, when the app went live, meant that there was very little local generation in most cases to pull down the headline figure from the BMRS. To improve the differentiation in the displays it was decided to introduce additional colour bandings (sub-bandings) to the display of the carbon intensity so that the user would have additional visual cues for assessing the best time for the mix.

The App is continuing in operation and is supported by the developer under their standard support terms. It remains hosted in the original locations, at Hyve. A follow-on project is being scoped to adjust/improve the app in response to user feedback gathered from the initial implementation and to make the data available for use by external third parties.

## 9.1 Products/Services Required

The key elements to allow for successful replication of this project were:

- External data feeds – BMRS and Weather feeds (DarkSky);
- Internal engagement with FNT/PSD projects and BAU systems support providing data sets;
- Data modelling tools (solar response) and data sources (UKHO almanac data, Government carbon intensity figures;
- Internal engagement with Corporate Comms for marketing;
- Internal engagement with Digital Comms for App creation and general design support;
- Developer support – app/website design/develop/test/deploy/operate/support;
- Hosting Support – External hosting service for the App, outside the WPD firewalls;
- Penetration Testing Service for security checks;
- Design, marketing and user engagement/feedback analysis from specialist Carbon interest organisations (Carbon Trust).

## 10 Data Access Details

When Western Power Distribution gathers significant amounts of data during the execution of innovation projects, our innovation strategy requires us to actively seek to share this data with interested parties, where this is possible and not covered by confidentiality restrictions. As the project did collect a significant amount of data at the BSP level and further developed an approach to app production, the project highlighted the possibility of implementing an extension to the Carbon Tracer Project called "Carbon Portal" which would make the App data available for onward use by third parties who are better placed to leverage such data for the purposes of customer engagement, an area which is certain to be become more important as new innovations like electric vehicles become more popular.

Issues to be resolved to achieve this will include licencing for derived information which uses external data feeds along with resolving the position for other licenced material; hosting mechanisms and access routes (API, bulk download etc.), marketing/publicity of the availability of the data via this new delivery channel, support for third party developers or data users.

The main live app data for the Carbon Tracer is located on hosted servers covered by service contracts with the project service providers (Enigma and Hyve). The animated/derived data which has the instantaneous values available based on the application of computational algorithms is what serves the app and website. There is also the source, static data which is used as the basis of the animated dataset. This is held in CSV/Text file format.

## 11 Foreground IPR

The project implemented a simplified computational mechanism, which is itself described earlier in this document, for informing customers of the instantaneous carbon intensity of their electricity supply. This is based on knowing the instantaneous demand, local generation makeup at the same time and grid infeed breakdown by fuel type making up any difference between demand and local generation and with the variability of the weather and national infeeds provided by live data feeds. With a fuel split and fuel mappings table of information, the app can then has all it needs to work out the details to be presented to the users.

Our method also developed a set of screens which together provided the required functionality in an ergonomic and readily understood format. This included the Now, Today, History and Forecast structure and the location selector. A follow on project will implement access APIs permitting open source type access to our carbon intensity data (as documented here) for those best placed to make use of this.

# 12 Planned Implementation

The App and website are now fully live, so in that sense the project was not a trial implementation that would need further work to become a fully rolled out BAU capability. Rather, the project is a proof of concept trial of a customer facing capability in a specific functional area (carbon footprint). Further similar customer (and/or internal) apps could be rolled out within WPD at any time using learning gained during this project, making such implementations much easier to produce, although the sourcing of the necessary driving data remains the main challenge.

A number of repeatable steps have been identified in the App development process and these could be repeated if required in the course of preparation of a new app.

## 12.1 Knowledge Required

The main knowledge areas for the project are:

- Algorithm development for App main engine and supporting functions including time / location analysis (for local noon), solar output as function of time and weather, wind output as a function of wind speed, scaling of other forms of generation;
- Familiarity with the location of data sources within the business and how to access and marshal the various contributing elements into a usable dataset for the app;
- App /website design, software development, hosting and support (mainly subcontracted to specialist supplier);
- User ergonomics, user "psychology", user surveying and feedback processing;
- Marketing, publicity and ongoing support to users;
- Analytics processing and feeding back into App design.

these may form the basis of a follow on project to look at how App development (with data support) might be productionised / templated.

In particular, the ESA polygons (from another project), and the mechanism for locating a user on the network using these, could become a standard piece of library functionality for other apps/website facilities.

The whole map operation and icon set are also available for re-use.

Data was bespoked for this project and looked to another project doing strategic studies of the network for the load data, essentially the normalised demand profiles for the BSPs and the maximum demand values for each necessary to scale the normalised demand profiles to actual MW values at each required time/date. However it is readily apparent that this sort of approach is where the extra cost lies with app development and identification of datasets which can support such functionality is important going forward. The issue is that the data is often "derived" after much analysis and is not available in any standard business source repositories. To be truly reusable, the data must be regularly produced in an automated manner and be available for dissemination to interested parties both internally and possibly externally. The difficulty comes with the "special data" which requires analysis to derive it.

**One important point concerns the use of a global unique WPD internal system identifier called the Network Reference ID** which is unfortunately not attached to all objects in all data sources. To enable data re-use and save time in lookups (as well as to improve reliability in lookups) the Network Reference ID should be made available everywhere. This piece of work is not insignificant but would certainly pay dividends in the sort of future projects which can be envisaged for the DSO landscape. This one action could genuinely facilitate replication across many areas.

Perhaps the most reusable aspect of the project is the overall approach to App design, rollout and management. Features here include:

- App premise, top level design approach, main screen flows;
- Data sourcing and optimisation, update cycles;
- Lifecycle stages, durations for these and individual responsibilities;
- Preparation for go-live and operations;
- Use of marketing and marketing channels;
- Wireframing, trials and test user feedback;
- Tools for supporting testing;
- Analytics;
- Feedback and user engagement.

# 13 Other Comments

## 13.1 Acknowledgements

We would like to thank the following people and organisations for their help during the development and launch of the app:

- Andrew Spencer and Andrew Webster (Activating Customer Engagement)
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- Dr Kevin Gurney (Hestia)
- Nadeem Sheik (OPower)
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- Gwent Energy CIC
- Bath and West Community Energy
- Cardiff Community Energy
- Fal Energy Partnership
- Harbury Energy Initiative
- Tamar Energy Community
- Gower Power
- Llangattock Green Valley
- Swansea Community Energy
- Transition Bro Gwaun
- Wadebridge Renewable Energy Network
- South Dartmoor Community Energy

- Exeter Community Energy
- Ponoma Solar
- West Solent Solar Co-operative Limited
- REGen
- Cornwall Council
- Plymouth Energy Community
- Teign Energy Communities
- Community Energy Wales
- Community Energy England
- South Brent Community Energy
- Sharenergy
- Talybont Energy
- Bristol City Council
- UK Hydrographic Office, Almanac data for Equation of Time computation in UKHO Publication AIS 58
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- Smart Grid Consultancy for data preparation, algorithms and high level design
- Enigma Interactive, App detailed design and implementation

## Contact

Further details on replicating the project can be made available from the following points of contact:

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## Glossary

| Abbreviation | Term |
|---|---|
| BMRS | Balancing Mechanism Reporting Service (Elexon) |
| CI | Carbon Intensity |
| CSV | Comma Separated Values. A file format where data elements are separated by commas on each row and structured in multiple rows for each new record. CSV data is easily imported into inspection and analysis programs such as MS EXCEL. |
| DNO | Distribution Network Operator |
| DNV | UKPN Project, Distribution Network Visibility |
| DSM | Demand Side Response |
| EAM | Enterprise Asset Management (system). For WPD this is CROWN. |
| ENW | Electricity North West |
| ESA | Electricity Supply Area. BSP based in this analysis, each of some 266 ESAs covering the whole of WPD are defined as geographic polygons whose boundary is the limit of the feeders of each BSP/BSP group. |
| EV | Electric Vehicles |
| FNT | WPD Future Networks Team |
| HH | Half Hour (or Half Hourly) data points, being averages over this interval |
| LTDS | Long Term Development Strategy |
| NIA | Network Innovation Allowance |
| PowerON | Power on (Fusion), the WPD NMS system and also referred to sometimes as PoF. |
| RAG | Red/Amber/Green traffic light visualisation method |
| SCADA | Supervisory Control And Data Acquisition. Systems for remote monitoring and control operations via communications channel via which analogue values are |

| Abbreviation | Term |
|---|---|
| | returned from the remote sites to the centre (PowerON). |
| VBA | Visual Basic for Applications, Embedded Excel programming language |
| WPD | Western Power Distribution |

## Reference Documents


1. Carbon Tracer Background Research (CT). Version 2.
2. Carbon Tracer Requirements Specification (WPD). Requirements Specification V2.2 dated 4/7/2017
3. Carbon Tracer Functional Specification (Enigma)
4. The Equation of Time corrections in UKHO Publication AIS 58 are from HMNAO, UKHO (UK Hydrographic Office).
5. UK Department for Business, Energy and Industrial Strategy, Fuel Mix Disclosure Data Table. (The information constitutes the ‘fuel mix disclosure data table’ as defined in The Electricity (Fuel Mix Disclosure) Regulations 2005. The data are for the disclosure period 01/04/2015 – 31/03/2016).
6. The solar radiation model used is solrad (version 1.2), A solar position and radiation calculator for Microsoft Excel/VBA implemented by Greg Pelletier of Washington State Department of Ecology, Olympia, WA. (With permission of the author).
7. The Regen reports are named “Distributed generation and demand study Technology growth scenarios to 2030”. There are now 4 of these reports, 1 for each licence area.
8. The corresponding WPD report to [7] is called “Shaping Subtransmission to 2030”. There is also one for each licence area. All the reports can be found on the WPD website.