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Northumbrian Water (Essex and Suffolk)

Statistical Analysis of Seven Water Efficiency Studies using Control Groups and Weather Influences

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Executive Summary

Essex & Suffolk Water (ESW) has routinely carried out water efficiency projects for the last 15 years. As part of these schemes the Company has installed thousands of water efficiency devices and encouraged customers to embrace water saving habits through behavioural change campaigns. These initiatives are monitored through the collection of three separate meter reads; these are used to calculate overall study savings. Through this process ESW has produced a measurable decrease in their customers' consumption.

However, ESW wanted to explore whether any further value can be extracted by re-analysing the results. This project was concerned with analysing and reporting the extent to which external factors influence demand during periods when water efficiency studies are undertaken. If external influences were found to be statistically significant a method of correctly adjusting for them was to be developed and reported upon in order that ESW staff can make use of the method on the analysis of future studies.

Objectives

The study objectives were as follows:

a) Calculate the overall savings achieved using the meter measurements provided for each study.
b) Characterise the pre and post measurement periods for each study.
c) Analyse and compare study group demographics with those contained within the control group PCC properties.
d) Select most appropriate PCC pre and post consumptions for each study and test for statistical significance.
e) Where appropriate use the calculations in d) above to adjust the results from a) above.
f) Where PCC adjustments have been made compare weather conditions for those periods as evidence to support the reasons for the demand changes.

Approach

Seven studies were included in the analysis and these included both domestic and commercial retrofit schemes. Measured water consumption data was used to calculate the mean pre and post intervention consumption per day at each property. The difference between the pre and post consumptions was calculated for each property.

Results

The findings of the analysis are summarised as follows:

1. Although all of the seven water efficiency studies were similar in scale, contained similar style of interventions and broadly similar water saving messages they returned very different short term results.
2. All studies contained a rolling programme of water audits lasting several months. This resulted in non-synchronous pre and post audit meter measurements. In turn,

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this casts doubt on whether a single pre and post audit period can be defined which represents a study group of properties. A control comparison based upon individual property measurement periods requires consideration.

3. The demographic mix described by Acorn category is very different between the studies. In addition, the PCC control (DCM monitor) does not match any of the studies' Acorn mix. If matching demographics becomes important then developing a method of translation and adjustment is required.
4. Using single fixed pre and post control periods is not appropriate because the water efficiency studies are undertaken on a rolling programme methodology undertaken over many months.
5. Using the individual household pre and post intervention period is a valid method but returns low change numbers. Therefore the cost benefit of undertaking this form of analysis requires careful scrutiny. The added value arising from calculating adjustment numbers in this way is very small.
6. Acorn breakdown of the current DCM is not possible due to the small sample size within the Acorn groupings. This results in the sample not being capable of delivering statistically significant results.
7. Schools in the water efficiency study group totalled 38. The individual school results varied widely (-11 m^3 to +11 m^3/school/day).
8. The 528 schools which formed part of the control group had widely spaced meter read periods. The vast majority were read every 6 or 12 months. This measurement method is not sufficient in resolution to inform the pre/post control analysis.
9. To be able to be used as a control each control group school should be read weekly ideally or possibly monthly. Achieving this would be costly and of doubtful value.
10. The most likely method of illuminating the schools intervention results further is to take more measurements within each school. Typically numbers of devices, device types, flow reductions, etc. This could be supported by statistical analysis if required.
11. It is recommended not to pursue a control adjusted results method for the schools projects.
12. The size and measurement strategy of the current DCM requires attention if it is going to be used as an effective control for water efficiency studies.
13. The extended nature of the current water efficiency studies, adopting a rolling programme approach, results in the process being to some extent self-regulating. The method of application diminishes the need to use control groups for adjustment.

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1 Introduction

Essex & Suffolk Water (ESW) has routinely carried out water efficiency projects for the last 15 years. As part of these schemes the Company has installed thousands of water efficiency devices and encouraged customers to embrace water saving habits through behavioural change campaigns. These initiatives are monitored through the collection of three separate meter reads; these are used to calculate overall study savings. Through this process ESW has produced a measurable decrease in their customers' consumption.

However, ESW wanted to explore whether any further value can be extracted by re-analysing the results. This project was concerned with analysing and reporting the extent to which external factors influence demand during periods when water efficiency studies are undertaken. If external influences were found to be statistically significant a method of correctly adjusting for them was to be developed and reported upon in order that ESW staff can make use of the method on the analysis of future studies.

2 Study objectives

The study objectives were as listed below:

a) Calculate the overall savings achieved using the meter measurements provided for each study.
b) Characterise the pre and post measurement periods for each study.
c) Analyse and compare study group demographics with those contained within the control group PCC properties.
d) Select most appropriate PCC pre and post consumptions for each study and test for statistical significance.
e) Where appropriate use the calculations in d) above to adjust the results from a) above.
f) Where PCC adjustments have been made compare weather conditions for those periods as evidence to support the reasons for the demand changes.
g) Report on all of the above.

3 Studies included and data provided

Seven studies were included in the analysis. These are detailed in the Table 1.

Table 1 Water Efficiency Studies included

Name	Type	Approximate Dates	Location
H2eco Phase 1	Domestic Retrofit	01-01-08 to 01-04-08	Chelmsford, Essex
H2eco Phase 2	Domestic Retrofit	01-06-08 to 24-09-08	Chelmsford, Essex
H2eco Phase 5	Domestic Retrofit	07-10-10 to 01-04-10	Wickford, Essex
H2eco Phase 6	Domestic Retrofit	15-07-11 to 23-12-11	Basildon, Essex
Schools Project Ph 2	Commercial Retrofit	14-07-10 to 31-03-11	Southend-on-sea
Shower 'n' Save	Product Trial	30-08-11 to 20-12-11	Writtle, Chelmsford
Ecobeta Project	Domestic Retrofit	01-03-07 to 31-07-07	Chelmsford, Essex

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The following data files were provided by Essex & Suffolk Water:

1. Access file “H2eco Phase 1 & 2” containing meter reads and demographic data.
2. Access file “H2eco Phase 5 & 6” containing meter reads and demographic data.
3. Access file “Encoded_Database1” containing Ecobeta study meter reads.
4. An excel file “Study of Water Use Data for Artesia” containing per capita consumption (PCC) split into Suffolk and Essex areas.
5. An excel file “Shower 'N' Save Data for Artesia” containing meter reads.
6. An excel file “Schools Phase 2 Data for Artesia” containing meter reads.
7. An excel file “Acorn Data Final” containing demographic data for the Ecobeta, Schools Ph2 and Shower n Save projects.
8. Four excel files “Weather Data for Artesia 2007_10” containing temperature and rainfall for years 07, 08, 09 and 10.
9. Weather data for 2011 was obtained from www.wunderground.com” by Artesia staff.
10. An excel file” PCC Acorn Data” containing demographic data for PCC control.
11. An excel file “Schools_control_group_for_artesia” containing non study school data.

The meter readings were used to calculate the mean pre and post consumption per day at each property. The difference between the pre and post intervention consumptions was calculated for each property. A positive difference indicates a reduction in consumption (i.e. a daily saving) and a negative difference represents an increase in consumption.

4 Overall savings achieved for each study

All meter read volumes (expressed in cubic metres) and their associated dates were converted into mean pre and post intervention consumptions for each individual property. The minimum amount of data was removed from the samples with the exclusions rules applied. Data has been excluded when:

a) Either pre or post data reads were not complete.
b) The calculated consumptions (pre or post intervention) returned negative consumptions.
c) A mean daily consumption for any property was in excess of 1500 litres/day.

Exclusion rules a) and b) typically removed 50 up to 100 properties from each of the domestic studies whilst c) removed typically only 10 properties.

The normality tests for the individual property savings (differences pre minus post intervention consumptions) were borderline in most cases. For this reason both parametric and non-parametric savings significances were tested. The summary outputs are shown in Appendix A.

The parametric tests were undertaken using t-tests are only appropriate for normally distributed data. The non-parametric tests were carried out using Mann-Whitney techniques and are used when the data is far from normally distributed.

The following table summarises and compares the results from each technique. The most likely value is a simple mean of the difference value calculated using each technique.

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Table 2 Overall study savings – most likely saving value

Study	No. in sample	Parametric Diff	Non Parametric Diff	Statistically Significant	Most likely saving value
H2Eco Ph1	663	20.3	17.7	Yes	19.0
H2Eco Ph2	623	6.7	5.8	Borderline	6.3
H2Eco Ph5 (3wks)	740	-2.5	-11.9	No	Unclear due to large dispersion in measurements
H2Eco Ph5 (3-6wks)	608	15.1	6.5	Borderline	10.8
H2Eco Ph6	711	48.1	44.5	Yes	46.3
Ecobeta	238	38.9	34.5	Yes	36.7
Shower N Save	84	16.1	11.2	Borderline	13.7 but small sample size
Schools Ph2	38	772	821	N/A	797 but very small sample size

The results for H2Eco Ph1, Ph2, Ph6, Ecobeta and Shower N Save are reasonably consistent and broadly statistically significant. The measurement system for H2Eco Ph5 has returned unreliable results.

The detailed results from each technique used are shown in tables in Appendix B.

Although each study was similar in scale, contained similar style of interventions and broadly similar water saving messages they returned very different short term results.

This highlights the fact that short term meter reads are at risk of containing variations driven by other factors.

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5 Pre and Post measurement periods

In order to initially assess the project period for each study the pre and post audit periods (in days) have been plotted as horizontal bar charts for the first, middle and last property measured. Below are typical examples the blue bar is the pre and the green bar the post period.
All the study plots are shown in Appendix C.

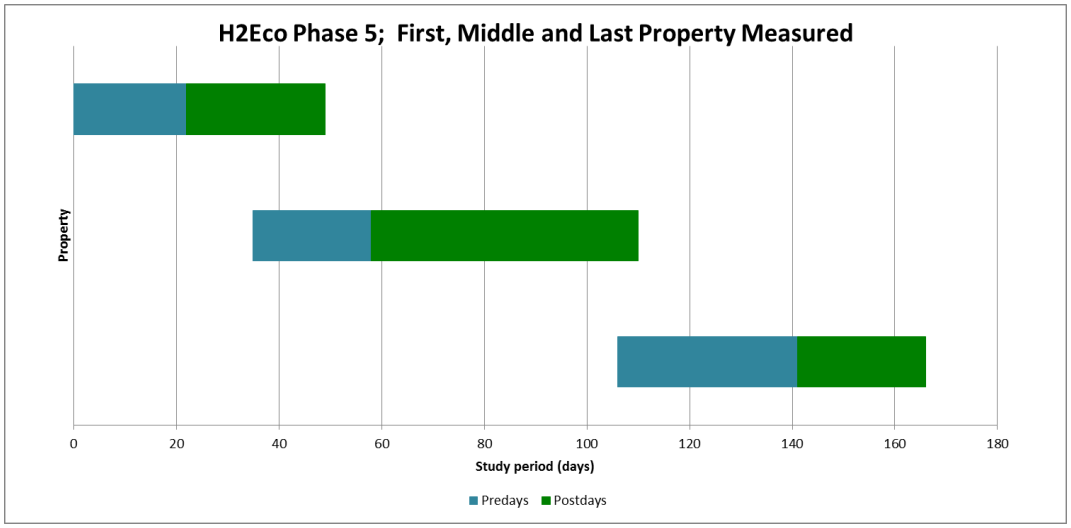

Figure 1 Typical Domestic H2Eco study

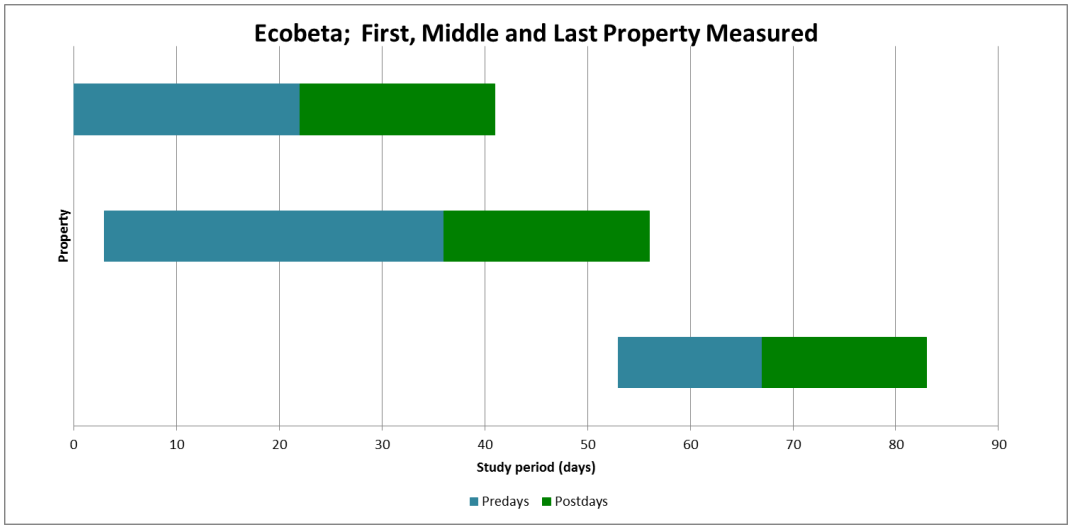

Figure 2 Typical Domestic Ecobeta study

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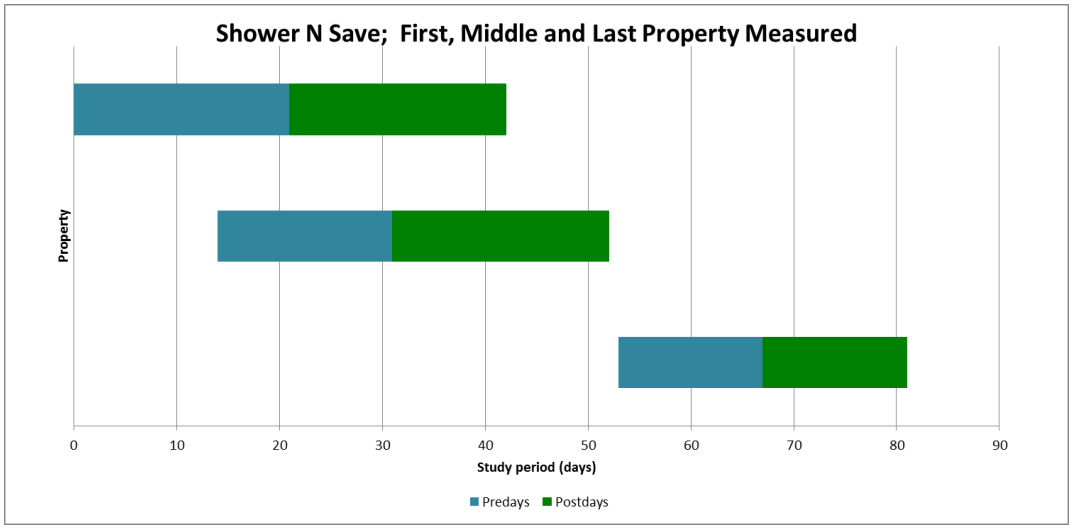

Figure 3 Domestic Shower 'n' Save Study

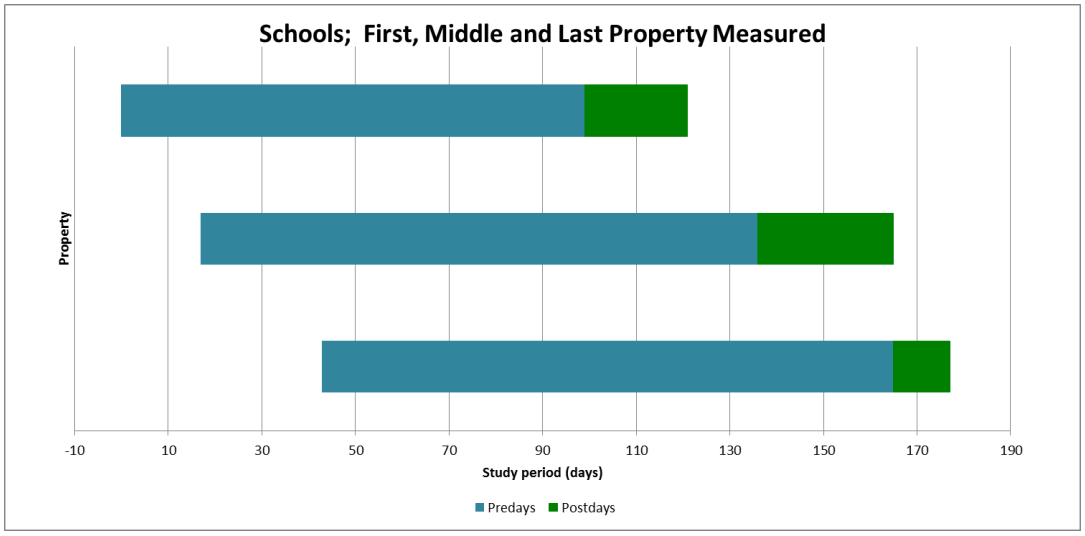

Figure 4 Schools phase 2 project

All the studies reviewed showed that properties were attended, intervened and measured over a prolonged non coincident period. All studies displayed had their last property pre measure period starting after the first property post period measurement had been completed with the exception of Schools 2 studies. The amount of variability in start and end period times has implications with regard to any comparison with a control.

Firstly, it casts doubt on whether a typical consistent pre and post intervention period could be defined for which control adjustment numbers would be appropriate.

Secondly, it generates the need to look at individual property pre and post intervention periods for every study which was not anticipated at the start of this project. This process is essential to generate individual property control consumption changes and aggregate these up for comparison against the overall study results.

All studies were undertaken in Essex and the PCC data provided was split into Essex properties and Suffolk properties. In addition Acorn categories for each property were supplied.

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Following on from the above it was decided to analyse the PCC in 5 separate ways for each study.

1. Using one single typical pre and post intervention period universally applied to all ESW DCM properties.
2. Using one single typical pre and post intervention period universally applied to Essex DCM properties only.
3. Using individual tailored property pre and post intervention periods for each and every property within each study using all ESW DCM properties.
4. Using individual tailored property pre and post intervention periods for each and every property within each study using all Essex DCM properties.
5. Using one single typical pre and post intervention period universally applied to all ESW DCM properties broken down into top level Acorn categories (1 to 5).

The results obtained are presented in section 7 of this report.

All studies contained a rolling programme of water audits lasting several months. This results in non-synchronous pre and post meter measurements. In turn, this casts doubt on whether a single pre and post period can be defined which represents a study group of properties. A control comparison based upon individual property measurement periods requires consideration.

6 Demographic mix for Study and Control groups

One aim of this study was to look at the demographic mix for each study. Acorn data was supplied to the project and the project team married each study property with the appropriate Acorn information. The demographic split for each domestic study is shown in the Table 3 below.

Table 3 Demographic split at Acorn top level for study properties and in ESW's DCM monitor

Study	Acorn Category				
	1	2	3	4	5
H2Eco Ph1	31.1%	3.3%	50.0%	6.0%	9.6%
H2Eco Ph2	25.9%	5.2%	23.8%	11.6%	33.6%
H2Eco Ph5	30.0%	0.4%	63.4%	4.6%	1.6%
H2Eco Ph6	23.2%	2.3%	17.3%	7.7%	49.4%
Ecobeta	51.6%	9.4%	30.5%	0.0%	8.6%
Shower N Save	52.4%	7.1%	20.2%	8.3%	11.9%
DCM PCC monitor (All ESW)	20.9%	6.1%	42.5%	25.5%	5.0%

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In addition the demographic split for Essex and Suffolk Water's (ESW's) DCM monitor was calculated and is shown in the last row of the Table 3.

Firstly, it is clear that the demographic mix is very different between studies. For example, H2Eco Ph6 had almost half of the properties in Acorn 5 whereas H2Eco Ph5 had less than 2% in Acorn 5. Other differences shown within Table 3. Secondly, the demographic mix for the DCM differs from all the domestic studies.

It is likely that water use will vary between the different groups and possibly contrarily at different times of the year and under fluctuating weather conditions. If this is so then consideration needs to be given to adjusting the control group demographic mix to align the combination with that of the study group.

The demographic mix described by Acorn category is very different between studies. In addition, the PCC control (DCM monitor) does not match any of the studies' Acorn mix. If matching demographics becomes important then developing a method of translation and adjustment is required.

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7 Control PCC consumptions for Pre and Post study periods

The PCC was analysed in 5 separate ways for each study using:

1. Using one single typical pre and post intervention period universally applied to all ESW DCM properties.
2. Using one single typical pre and post intervention period universally applied to Essex DCM properties only.
3. Using individual tailored property pre and post intervention periods for each and every property within each study using all ESW DCM properties.
4. Using individual tailored property pre and post intervention periods for each and every property within each study using all Essex DCM properties.
5. Using one single typical pre and post intervention period universally applied to all ESW DCM properties broken down into top level Acorn categories (1 to 5).

The results for methods 1 to 4 are shown in Table 4. An * denotes a statistically significant result. The changes shown are pre minus post therefore positive values are reductions and negative values increases.

Table 4 **PCC control changes in consumption using different pre and post periods**

Study	All ESW DCM single pre post period Litres/prop/day	Essex Props DCM single pre post period Litres/prop/day	All ESW DCM individual prop pre and post period Litres/prop/day	Essex Props individual prop pre and post period Litres/prop/day
H2Eco Ph1	3.3 *	0.8	2.3 *	-0.1
H2Eco Ph2	-0.5	-0.19	0.2	0.6
H2Eco Ph5	-2.0	-5.4 *	-0.2	-1.1 *
H2Eco Ph6	-3.4 *	-8.0 *	0.8 *	-1.0 *
Ecobeta Study	1.8	2.9	0.6	1.5 *
Shower N Save	1.8	1.1	1.7 *	2.8 *

There are 11 statistically significant results out of the 24 shown. Firstly, taking the single pre/post periods; the “all ESW properties control” shows a statistically significant change for Phases 1 and 6 of 3.3 and -3.4 l/prop/d respectively; the “Essex only properties control” shows a statistically significant change for Phases 5 and 6 of -5.4 and -8.0 l/prop/d respectively. The scale of these changes is such that they are likely to introduce a material change to those particular studies. However, it can be seen from section 5 that it is very doubtful that a single

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pre/post period can be representative of any study. There is sufficient doubt to make adjustment using these numbers as being inappropriate.

Secondly taking the individual household pre/post periods; the "all ESW properties control" shows a statistically significant change for Phases 1, 6 and shower n save of 2.3, 0.8 and 1.7 l/prop/d respectively; the "Essex only properties control" shows a statistically significant change for Phases 5, 6, Ecobeta and shower n save of -1.1, -1.0, 1.5 and 2.8 l/prop/d respectively. The scale of these changes is such that they are not likely to introduce any material change to those particular studies. It can be seen from section 5 that this method of calculating the change in PCC control consumption is appropriate to be used as representative of any study. However all the change numbers are very low and within the quoted confidence interval of the savings calculated for all studies. For these reasons the viability of attempting PCC control analysis should be questioned. A view should be taken on the costs versus the benefit of attempting the individual household control method.

Using single fixed pre and post control periods is not appropriate because the water efficiency studies are undertaken on a rolling programme methodology undertaken over many months.

Using the individual household pre and post period is a valid method but returns low change numbers. Therefore the cost benefit of undertaking this form of analysis requires careful scrutiny. The added value arising from calculating adjustment numbers in this way is very small.

The results for method 5 are shown in Table 5. An * denotes a statistically significant result. The changes shown are pre minus post therefore positive values are reductions and negative values increases. Acorn breakdown of the DCM has been calculated and inspected.

Table 5 Savings for each domestic study broken down into Acorn

Study	Acorn Category				
	1	2	3	4	5
H2Eco Ph1	2.23	10.9	0.51	4.1	11.72 *
H2Eco Ph2	3.44	-0.94	-1.34	-2.56	-2.26
H2Eco Ph5	2.3	-12.66 *	-1.19	-3.00	-12.11
H2Eco Ph6	-4.9	-3.9	-3.9	-1.5	-2.85
Ecobeta study	4.49	29.7 *	-1.94	1.65	-3.46

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The Acorn breakdown results returned very few statistically significant results. (3 out of 25). If Acorn breakdown of the control PCC is thought to be important the size of the DCM sample needs to be increased to introduce more statistical significant results. In view of the limited value of the overall control method Acorn breakdown this is unlikely to become a requirement in the near future.

Shower N Save comprises only 84 properties not a sufficiently large to attempt to categorise down further.

The likelihood of achieving statistically significant results are improved in two ways. Increasing consistency of recorded measurements and increasing the sample size. Daily household water use is erratic so there is little opportunity to influence the consistency of measurement. The results indicate that the DCM currently used by ESW is not sufficiently large to allow meaningful breakdown into Acorn categories. It cannot be used to reliably calculate consumption adjustment numbers for water efficiency trial periods.

Acorn breakdown of the current DCM is not possible due to the small sample size within the Acorn groupings. This results in the sample not being capable of delivering statistically significant results.

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8 Schools analysis and control

The schools study comprises 38 water efficiency intervention schools which had between 1 and 4 water meters feeding each site. The total of all the meter consumptions were used to calculate the pre and post water use at each school. The mean consumption reductions were 800 litres per school per day which is shown in Table 2 in section 4. This reduction is a large enough number to attract interest in undertaking this type of work but there were considerable differences between schools.

The least successful school apparently increased its consumption by 11,187 litres per day and most successful result showed a reduction of 11,516 litres per day. Such is the scale of these numbers it may be beneficial to spend more time at these sites collecting further information and flow measurements to attempt to challenge these numbers and the reasons why.

The mean pre measurement period for the 38 schools was 118 days and the mean post period only 21 days. The short term nature of the post measurement reads may account for some of the volatility and consideration could be given to increasing the length of the post period measurement.

The control schools samples comprise 528 schools with flow measurements from 1st January 2008 until 1st November 2012. The boxplot in Figure 5 shows the time between meter readings for each school within the control group.

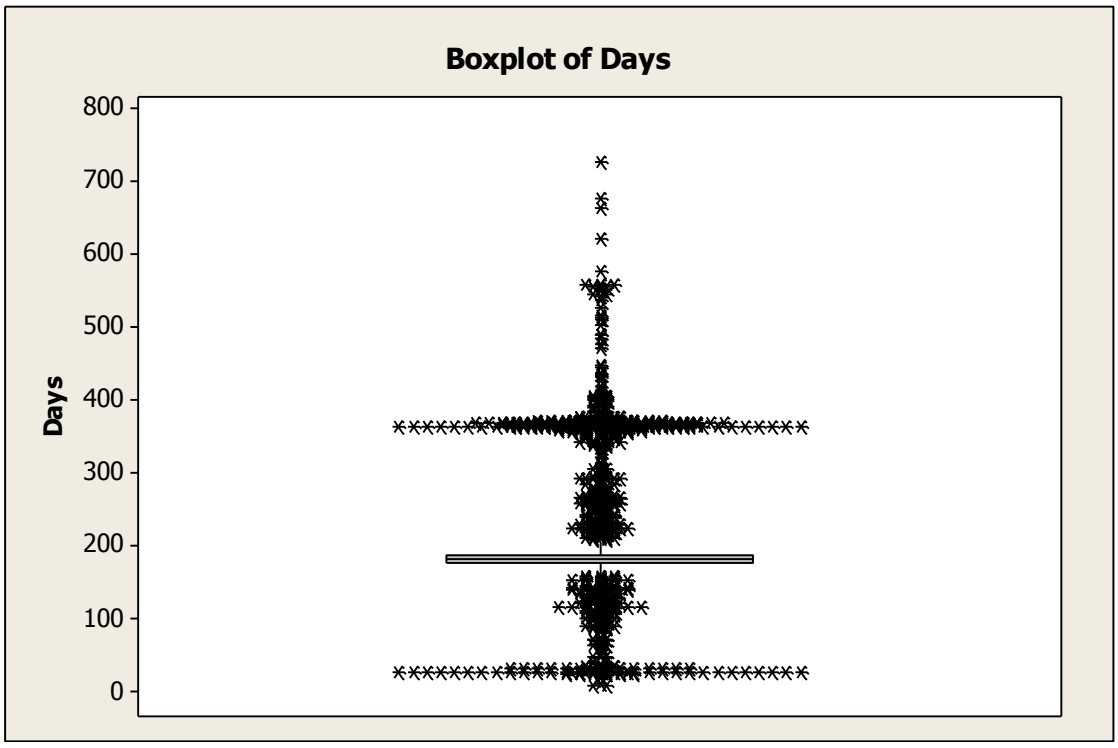

Figure 5 Boxplot of days between meter readings for each school within the control group

The first question raised is that the meter reads generally were too far apart in time to provide sufficient resolution to be used as a control. 50% of the control schools had 183 days (6 months) between meter reads, 40 sites were read every 30 days and 100 sites read only

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every 365 days (annually). Again this resolution of measurement is not sufficient to be used as a control again pre and post periods of study duration of the order of 30 days.

The mean pre control group consumption was 5114 litres/school/day.
The mean post control group consumption was 4969 litres/school/day.

This results in a reduction of 145 litres/school/day [-42,332] 90% CI.

This is not a statistically significant change.

Typical mean consumptions for control schools (litres / school / day)

College	8849
Infant	3406
Junior	4062
Nursery	1585
Primary	3884
Secondary	9103

Typical mean consumptions for study schools (litres / school / day)

Other	4006
Primary	5066
Secondary	8663

Schools in the water efficiency study group totalled 38. The individual school results varied widely (-11 m^3 to +11 m^3/school/day).

The 528 schools which formed part of the control group had widely spaced meter read periods. The vast majority were read every 6 or 12 months. This measurement method is not sufficient in resolution to inform the pre/post control analysis.

To be able to be used as a control each control group school should be read weekly ideally or possibly monthly. Achieving this would be costly and of doubtful value.

The most likely method of illuminating the schools intervention results further is to take more measurements within each school. Typically numbers of devices, device types, flow reductions etc. This may be supported by some modest statistical analysis if required.

It is recommended not to pursue a control adjusted results method for schools projects.

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9 Study results, PCC adjustments and weather

Summary graphs showing the study periods for all 7 studies are shown below. They comprise weather variables rain and maximum temperature plotted at the top. Immediately below the consumption profiles for the study control groups. At the bottom of each page the pre and post meter measurement periods are shown.

They show clearly 3 main characteristics.

1. That weather conditions vary greatly throughout the study period and it is generally recognised that weather influences demand.

2. The control group consumption does vary during the period resulting in having the potential at least to influence water efficiency study results depending upon the actual timing of the changes.

3. In all cases the variety of different starting audit and completions times across all study properties is such that it is not possible to define a single pre and post fixed period which is representative of the study group.

With regard to the DCM there are between 200 and 300 contributing domestic properties for which daily consumptions are calculated. However, less than 10% of these are actually logged or recorded on a daily basis. The majority of data is recorded every 30, 60 or 90 days or thereabouts. Average daily numbers are then calculated between these measurement periods. Whilst this is no doubt perfectly fine for the purpose which ESW collect these numbers it does have implications for their use as a control. Most pre and post periods are the order of 30 days or so in length and generally collecting control data at these intervals or greater will inevitably lead to significant proportions of the same measurement being contained within both the pre and post periods. This reduces the value and effectiveness of using the DCM as a control.

The size and measurement strategy of the current DCM requires attention if it is going to be used as an effective control for water efficiency studies.

One additional point on current implementation of water efficiency studies is that they are spread across such a prolonged time period that any periods of general changes in consumption are likely to apply to some study pre periods and some post periods contemporaneously in equal measure. In addition to this changes in control consumption and/or weather conditions often occur outside any pre or post period for many properties within the study group. Whether by design or accident it is a method of delivery which, in part at least, counteracts the need to use control groups.

The extended nature of the current water efficiency studies, adopting a rolling programme approach, results in the process being to some extent self-regulating. The method of application diminishes the need to use control groups for adjustment.

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H2Eco Ph1 - Weather, PCC, Mean Pre-post period and Individual pre-post periods.
Study Measurement Period - 2nd January 2008 to 1st April 2008

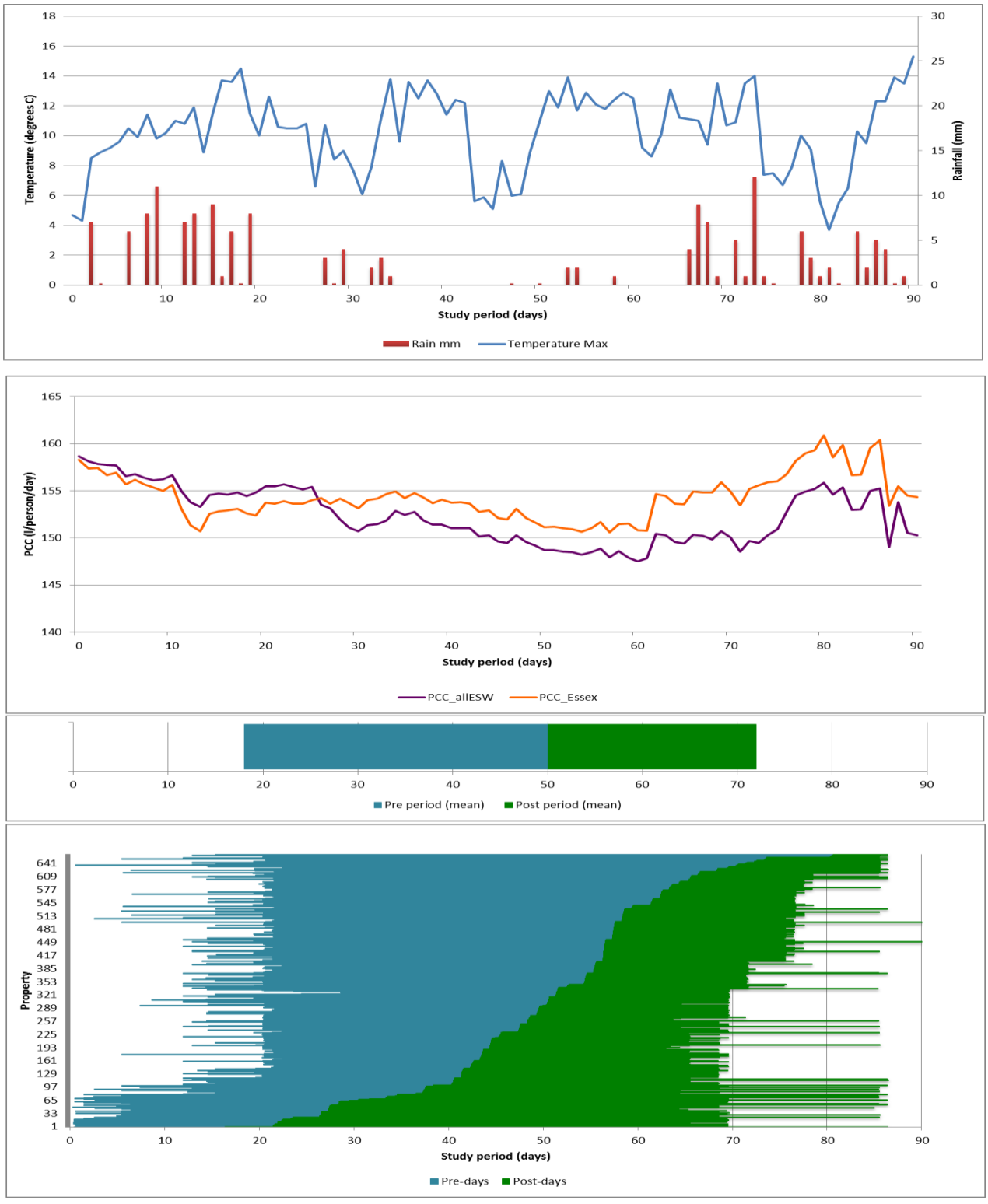

Figure 6 Weather, control consumption and household pre and post periods for H2Eco Ph1

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H2Eco Ph2 - Weather, PCC, Mean Pre-post period and Individual pre-post periods.
Study Measurement Period - 9th June 2008 to 24th September 2008

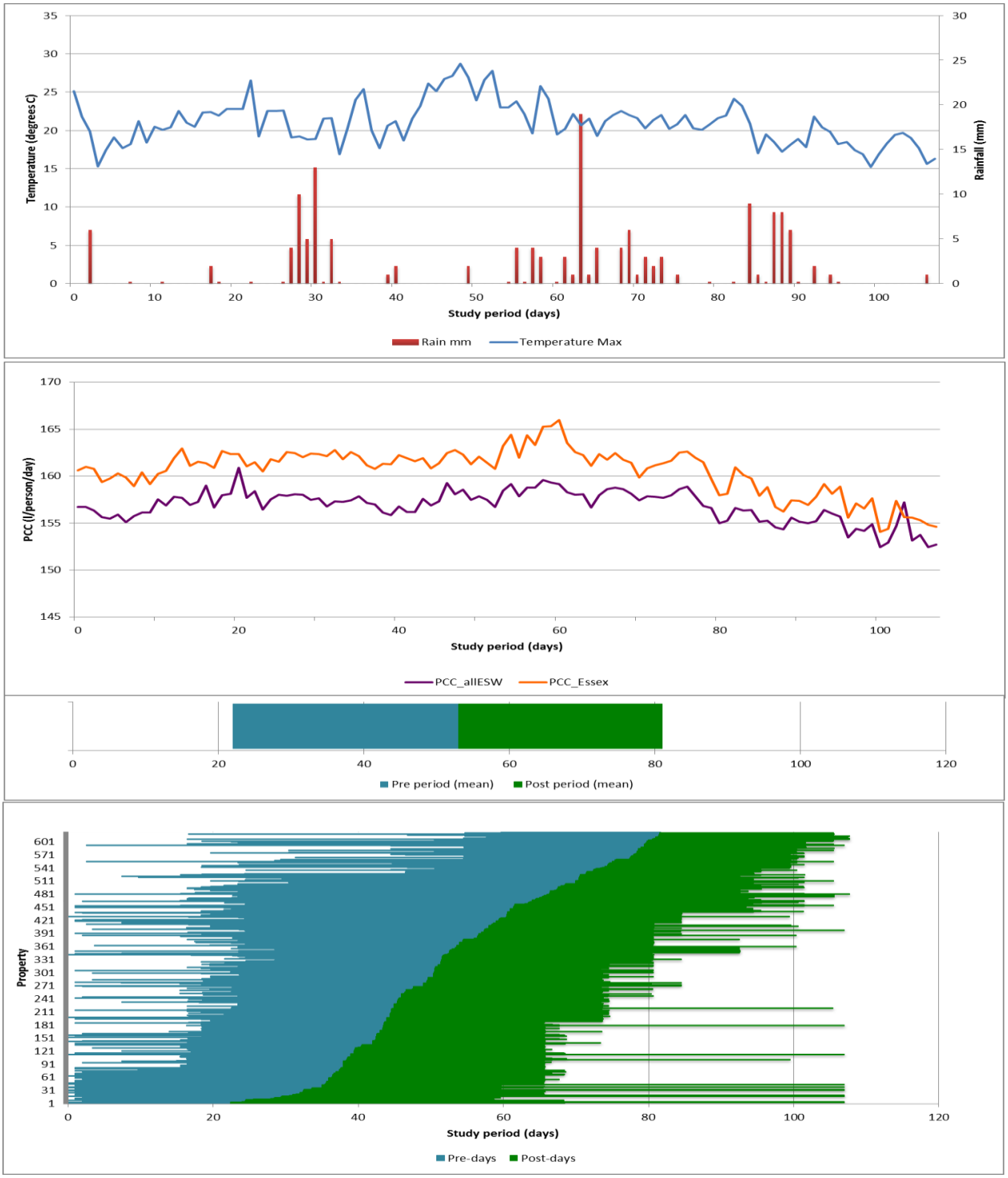

Figure 7 Weather, control consumption and household pre and post periods for H2Eco Ph2

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H2Eco Ph5 - Weather, PCC, Mean Pre-post period and Individual pre-post periods.
Study Measurement Period - 20th October 2010 to 4th April 2011

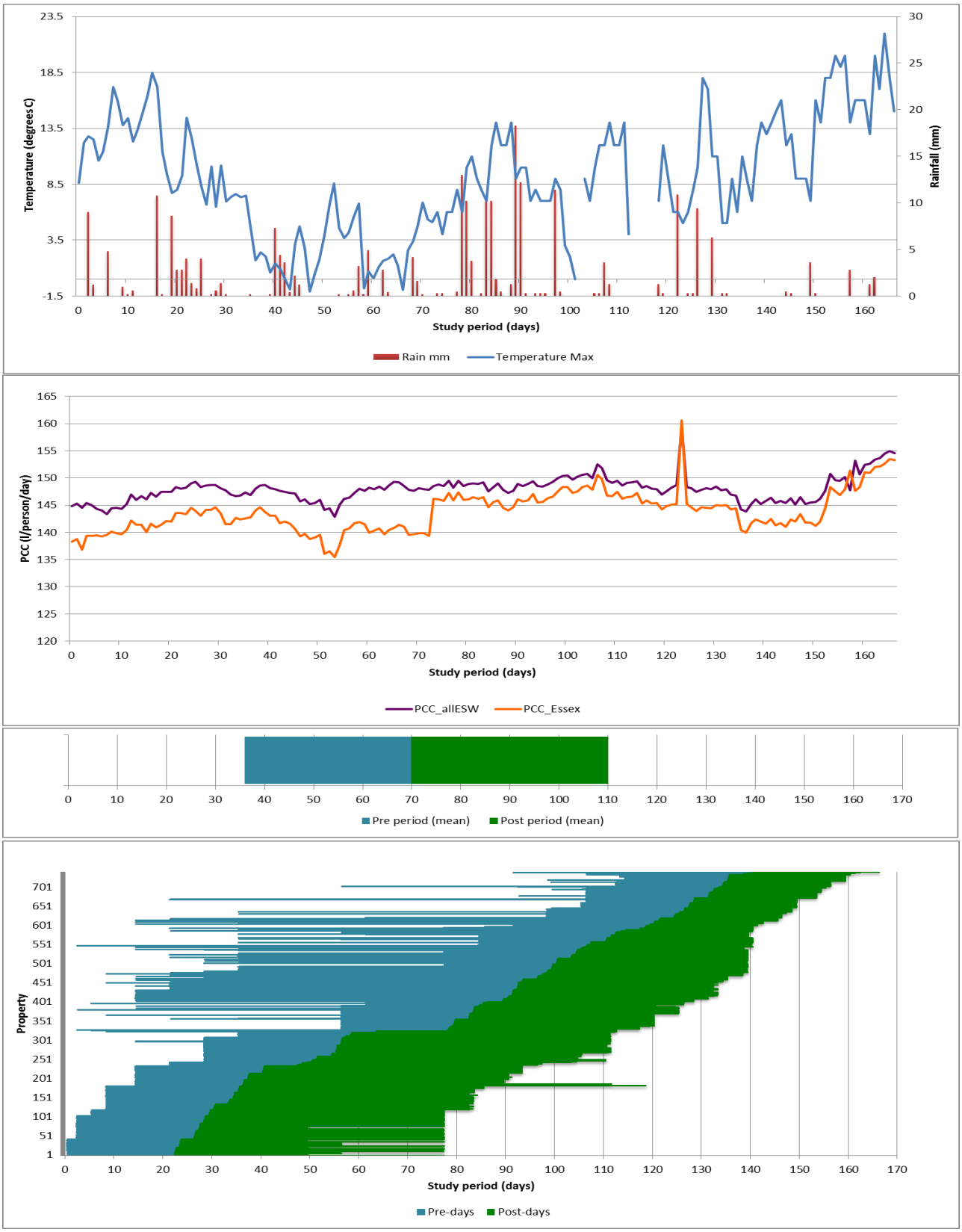

Figure 8 Weather, control consumption and household pre and post periods for H2Eco Ph5

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H2Eco Ph6 - Weather, PCC, Mean Pre-post period and Individual pre-post periods.
Study Measurement Period - 21st July 2011 to 6th January 2012

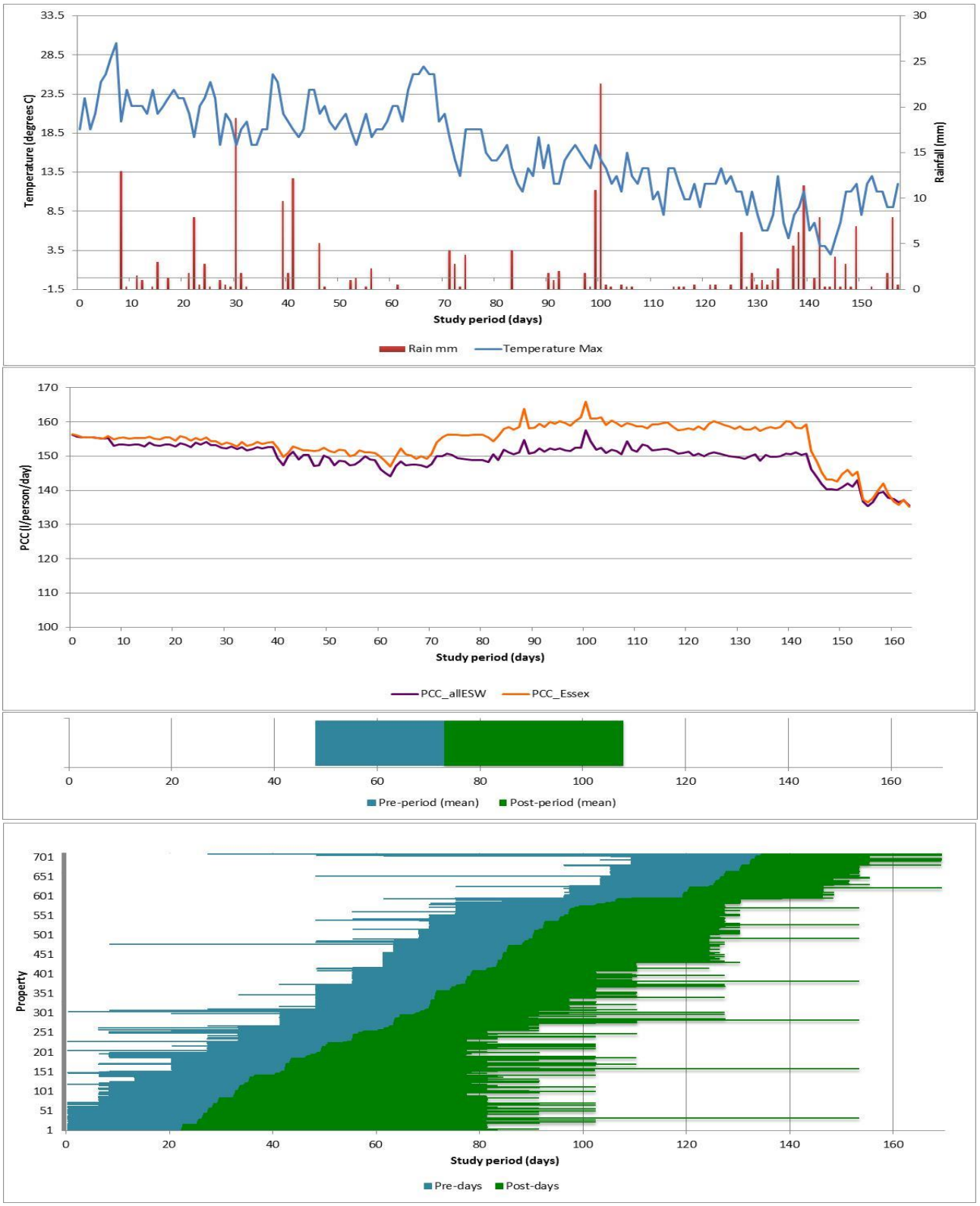

Figure 9 Weather, control consumption and household pre and post periods for H2Eco Ph6

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Ecobeta Study - Weather, PCC, Mean Pre-post period and Individual pre-post periods.
Study Measurement Period - 16th April 2007 to 19th July 2007

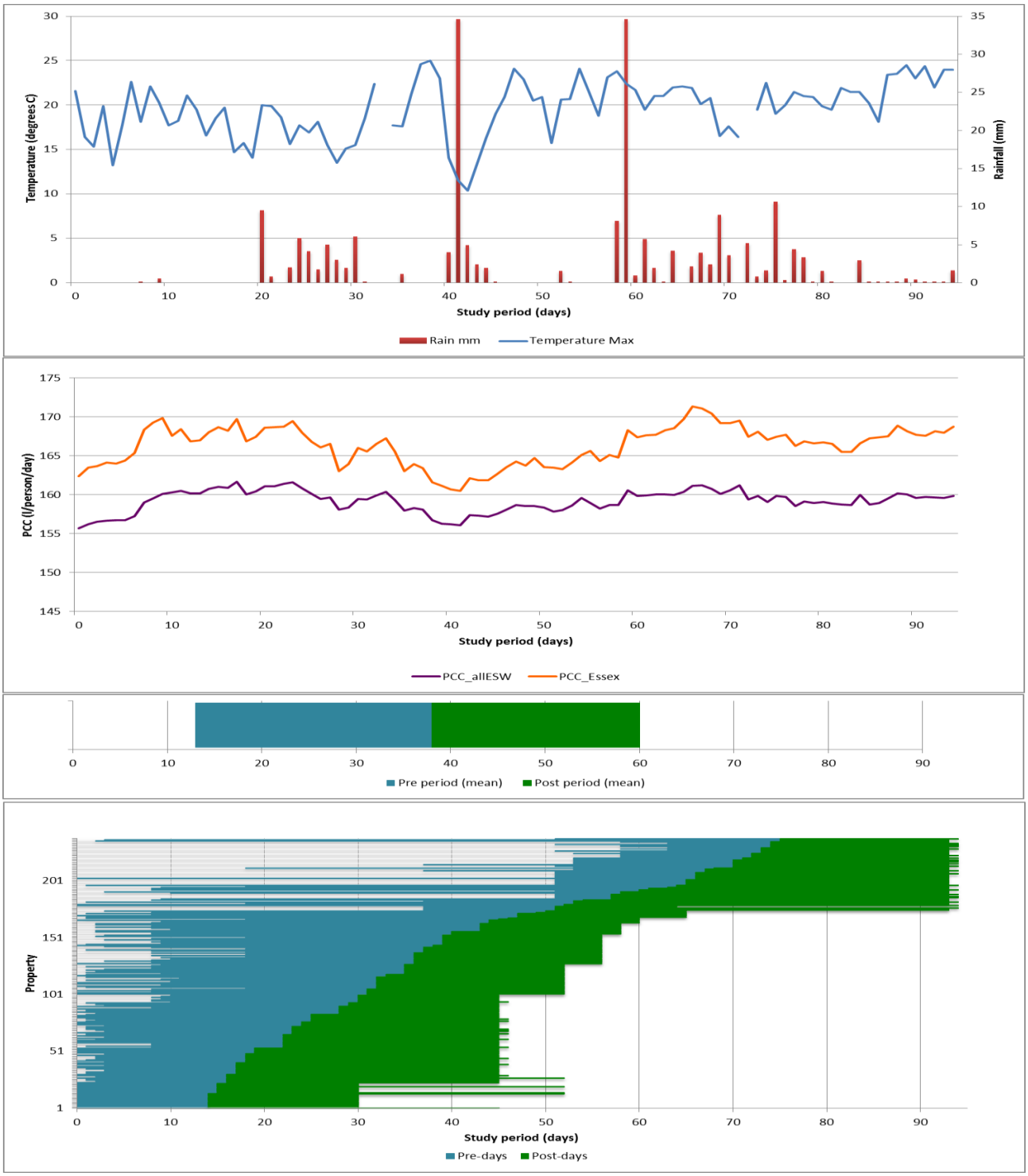

Figure 10 Weather, control consumption and household pre and post periods for Ecobeta study

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Shower N Save - Weather, PCC, Mean Pre-post period and Individual pre-post periods.
Study Measurement Period - 30th September 2011 to 20th December 2011

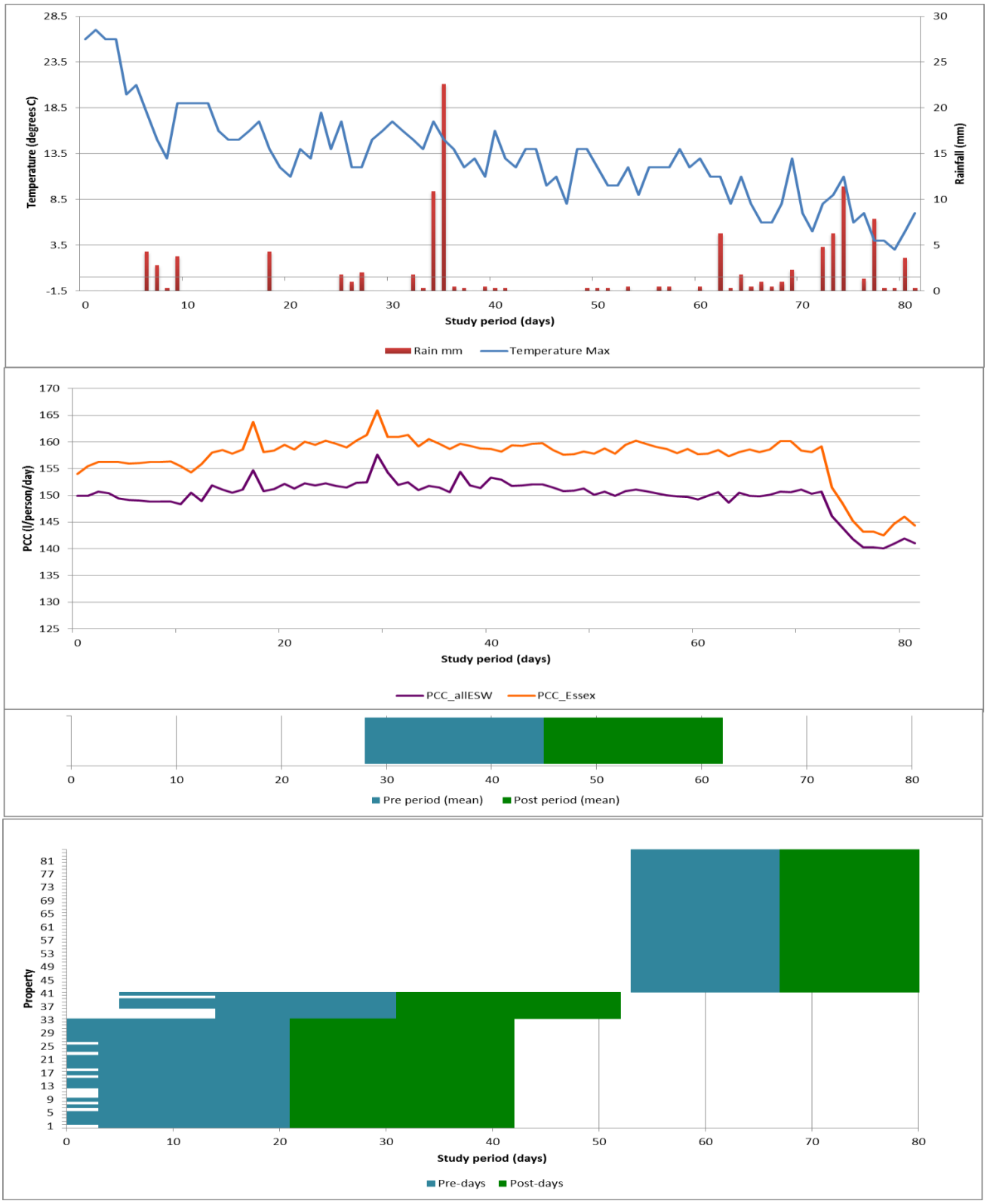

Figure 11 Weather, control consumption and household pre and post periods for Shower n Save

Schools 2 - Weather, Control cons, Mean Pre-post period and Indvdl pre-post periods.
Study Measurement Period - 13th September 2010 to 9th March 2011

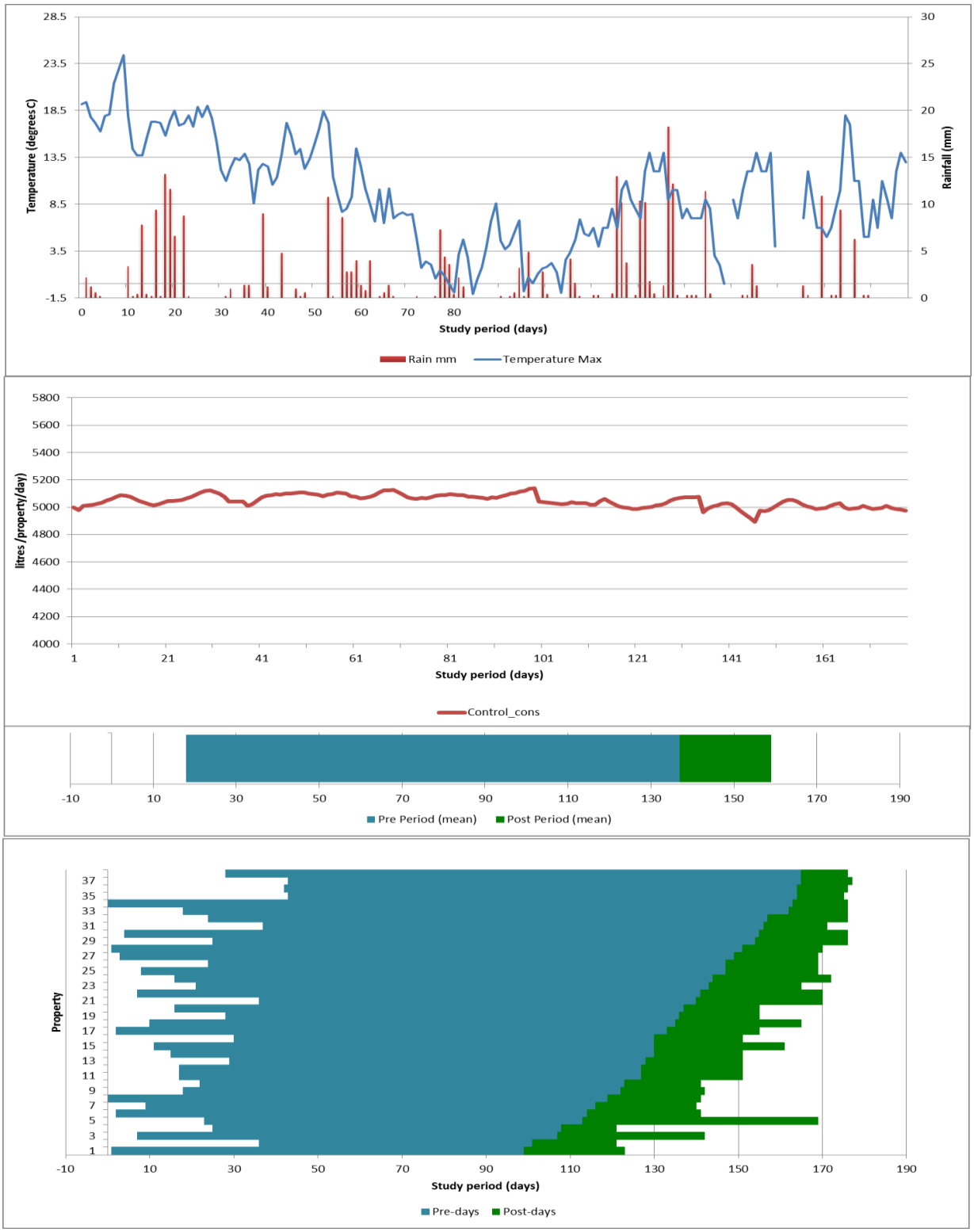

Figure 12 Weather, control consumption and household pre and post periods for School Ph2

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10 Findings and recommendations

The findings of the study are as follows:

1. Although all of the seven water efficiency studies were similar in scale, contained similar style of interventions and broadly similar water saving messages they returned very different short term results.
2. All studies contained a rolling programme of water audits lasting several months. This resulted in non-synchronous pre and post audit meter measurements. In turn, this casts doubt on whether a single pre and post audit period can be defined which represents a study group of properties. A control comparison based upon individual property measurement periods requires consideration.
3. The demographic mix described by Acorn category is very different between the studies. In addition, the PCC control (DCM monitor) does not match any of the studies' Acorn mix. If matching demographics becomes important then developing a method of translation and adjustment is required.
4. Using single fixed pre and post control periods is not appropriate because the water efficiency studies are undertaken on a rolling programme methodology undertaken over many months.
5. Using the individual household pre and post intervention period is a valid method but returns low change numbers. Therefore the cost benefit of undertaking this form of analysis requires careful scrutiny. The added value arising from calculating adjustment numbers in this way is very small.
6. Acorn breakdown of the current DCM is not possible due to the small sample size within the Acorn groupings. This results in the sample not being capable of delivering statistically significant results.
7. Schools in the water efficiency study group totalled 38. The individual school results varied widely (-11 m^3 to +11 m^3/school/day).
8. The 528 schools which formed part of the control group had widely spaced meter read periods. The vast majority were read every 6 or 12 months. This measurement method is not sufficient in resolution to inform the pre/post control analysis.
9. To be able to be used as a control each control group school should be read weekly ideally or possibly monthly. Achieving this would be costly and of doubtful value.
10. The most likely method of illuminating the schools intervention results further is to take more measurements within each school. Typically numbers of devices, device types, flow reductions, etc. This could be supported by statistical analysis if required.
11. It is recommended not to pursue a control adjusted results method for the schools projects.
12. The size and measurement strategy of the current DCM requires attention if it is going to be used as an effective control for water efficiency studies.
13. The extended nature of the current water efficiency studies, adopting a rolling programme approach, results in the process being to some extent self-regulating. The method of application diminishes the need to use control groups for adjustment.

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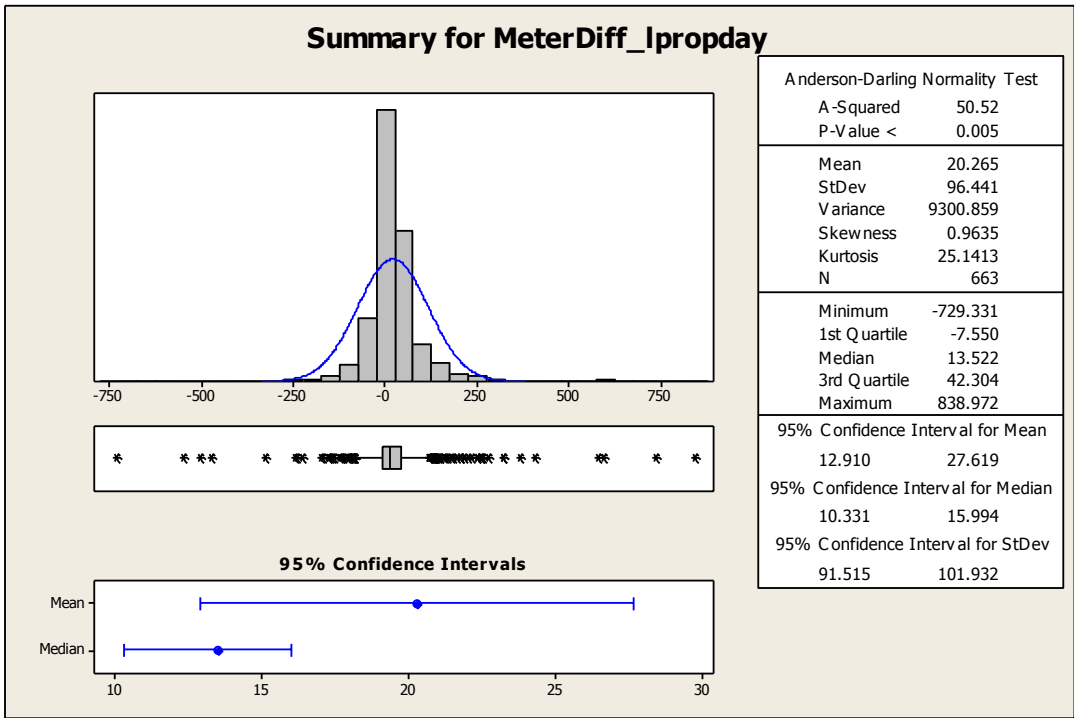
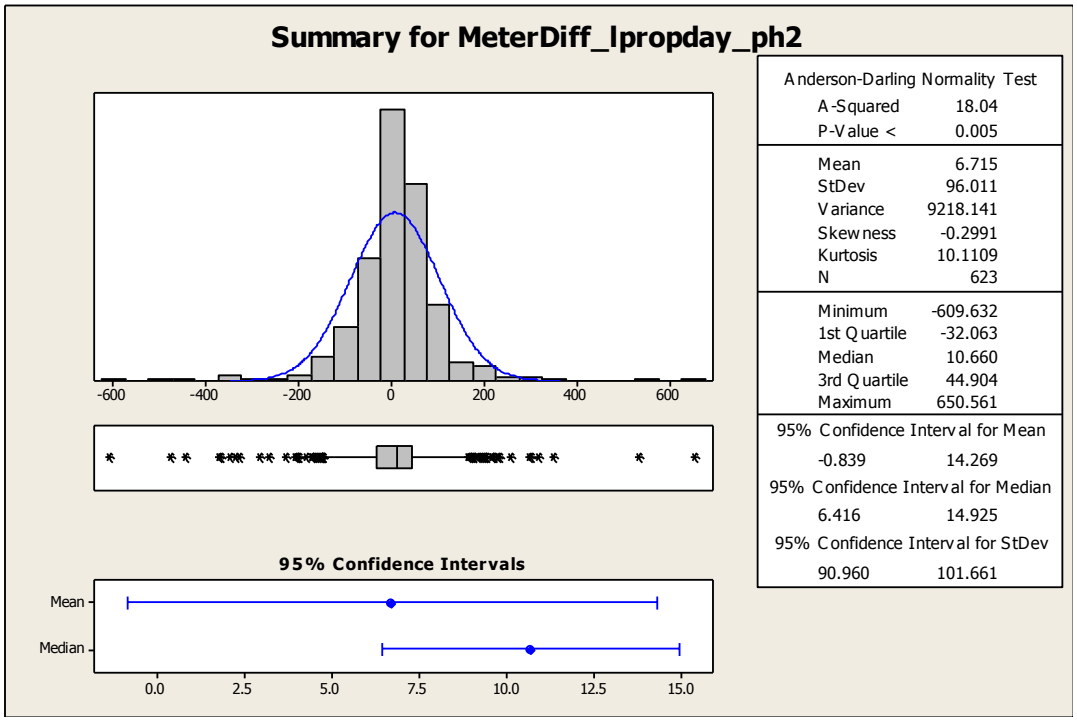
Appendix A Normality tests on savings

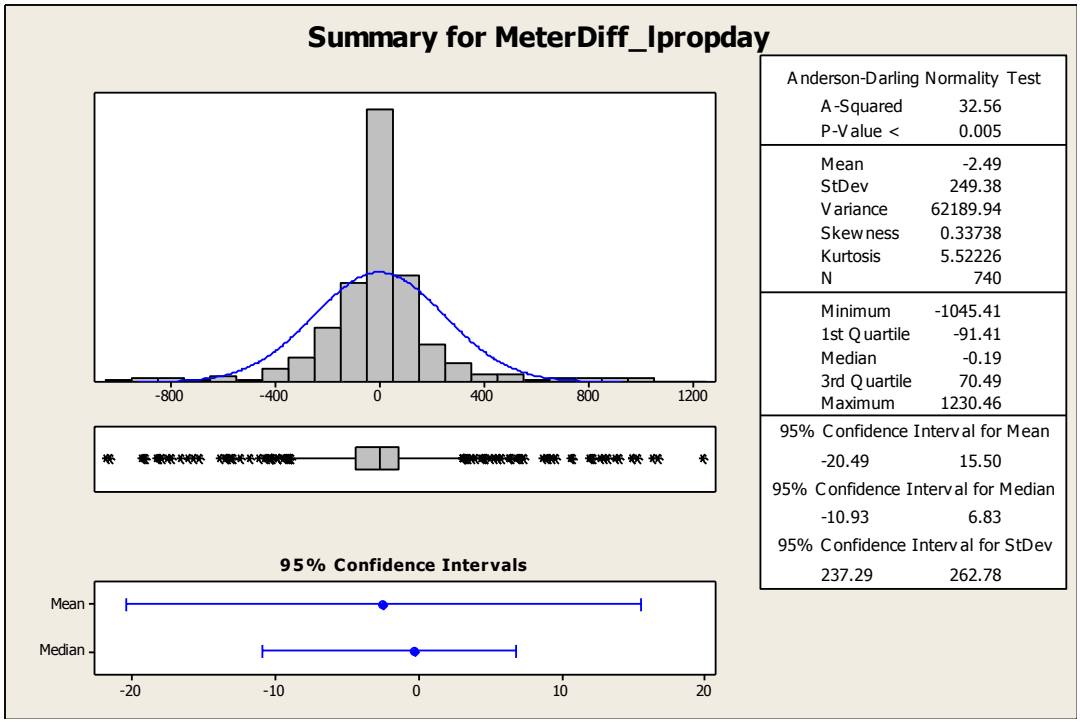
H2Eco Ph1



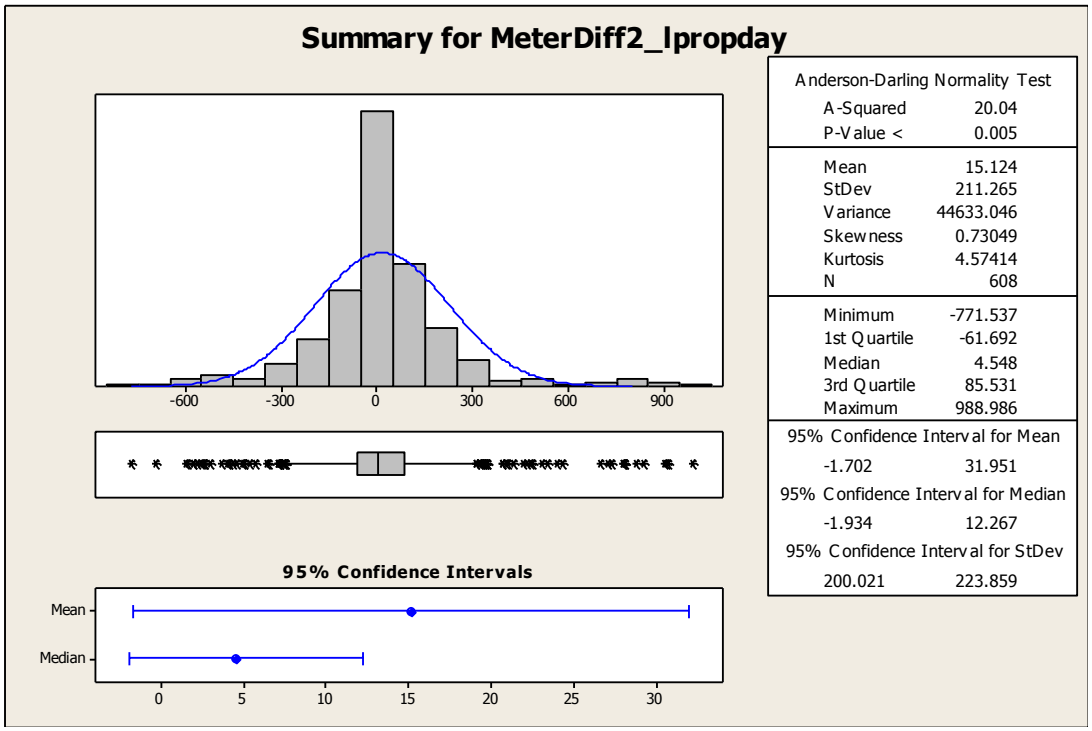
H2Eco Ph2



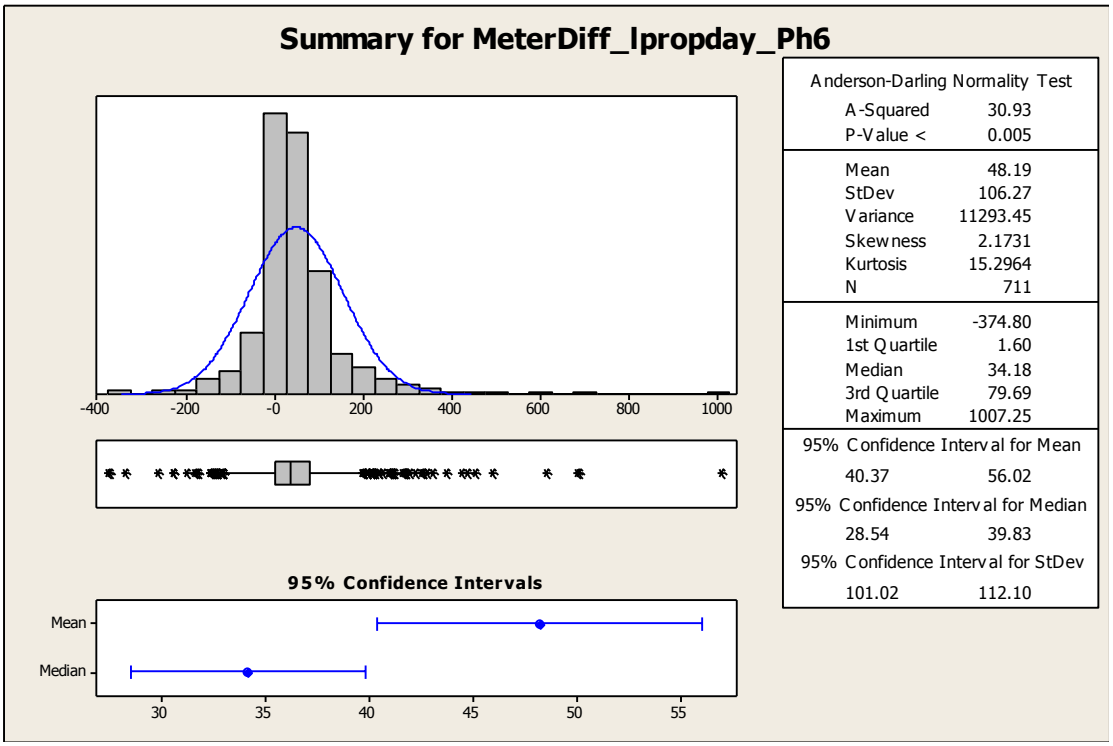
H2Eco Ph5 (3 weeks post)



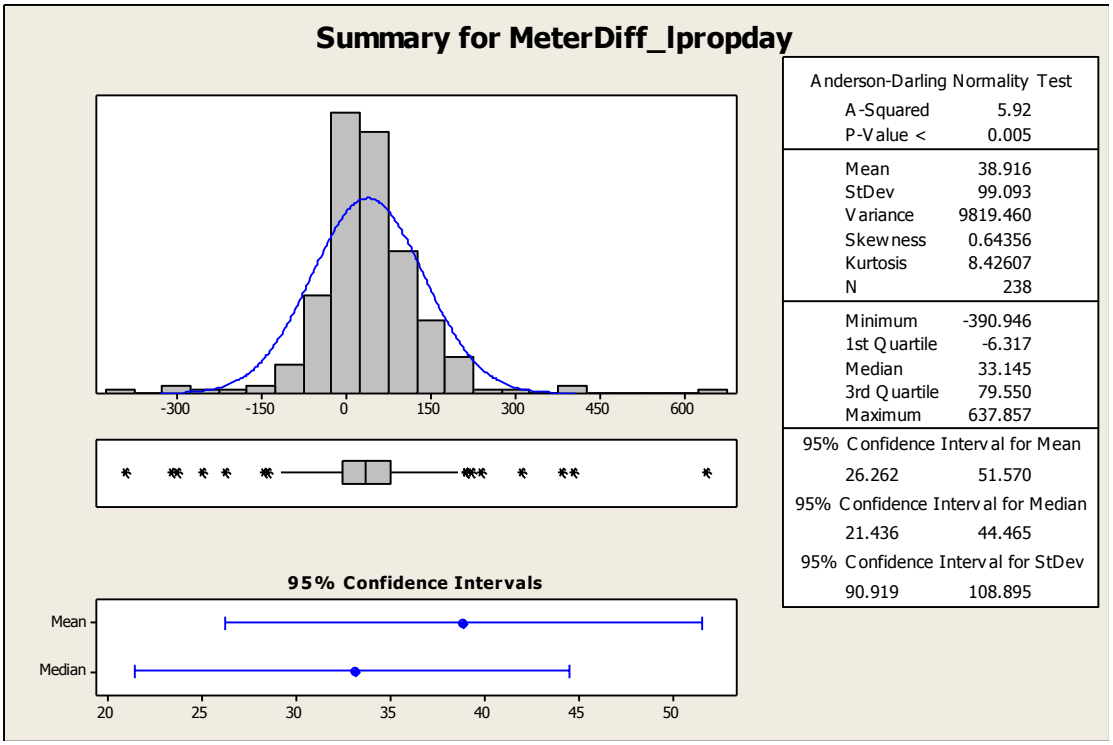
H2Eco Ph5 (3-6wks post)



H2Eco Ph6



Ecobeta Study



Appendix B Overall Savings Calculations Parametric and Non-Parametric

The results of these tests are shown in the table below. The *"No in Sample"* column contains the number of individual properties which remained after the exclusion rules were applied.

The calculation for difference (Diff column) is Pre minus Post therefore positive values indicate a reduction in consumption.

The right hand most column provides an indication of statistical significance. (Except for Schools; * stat sig not considered accurate due to small sample size and disparate nature of the different schools)

All consumption units are litres per property per day.

Results of Parametric t tests

Study	No in sample	Mean Precons	Mean Postcons	Diff	90% CI		Stat Sig
H2Eco Ph1	663	263.4	243	20.3	14.1	26.4	Yes
H2Eco Ph2	623	280.0	273.3	6.7	0.4	13.1	Borderline
H2Eco Ph5 (3wks)	740	282.9	285.4	-2.5	-17.6	12.60	No
H2Eco Ph5 (3-6wks)	608	292.06	276.94	15.12	1.0	29.2	Borderline
H2Eco Ph6	711	311.0	262.9	48.1	41.6	54.76	Yes
Ecobeta	238	325.7	286.7	38.9	28.3	49.5	Yes
Shower N Save	84	279.4	263.3	16.11	5.1	27.1	Yes
Schools Ph2	38	6804	6032	772	N/A	N/A	*

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Results of Non Parametric Mann Whitney tests

Study	No in sample	Mean Precons	Mean Postcons	Diff	90% CI		Stat Sig
H2Eco Ph1	663	234.8	218.1	17.7	6.4	29.2	Yes
H2Eco Ph2	623	253.5	250.0	5.8	-6.5	18.3	No
H2Eco Ph5 (3wks)	740	231.8	248.8	-11.9	-24.2	0.1	No
H2Eco Ph5 (3-6wks)	608	231.8	227.5	6.5	-5.63	19.7	No
H2Eco Ph6	711	277.0	225.1	44.5	31.4	57.6	Yes
Ecobeta	238	294.0	257.5	34.5	11.5	59.3	Yes
Shower N Save	84	250.4	245.9	11.2	-21.2	46.3	No
Schools Ph2	38	6537	5513	821	N/A	N/A	*

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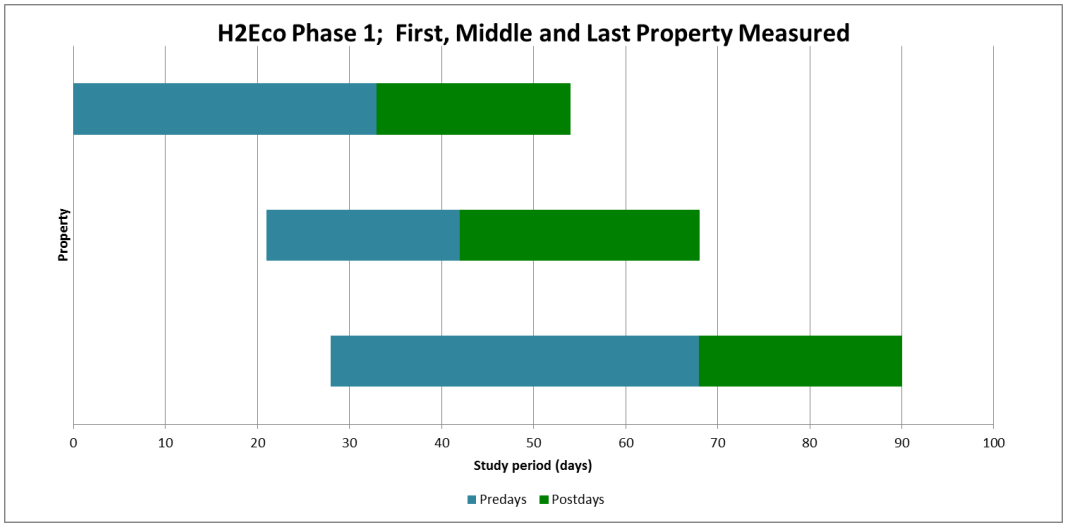
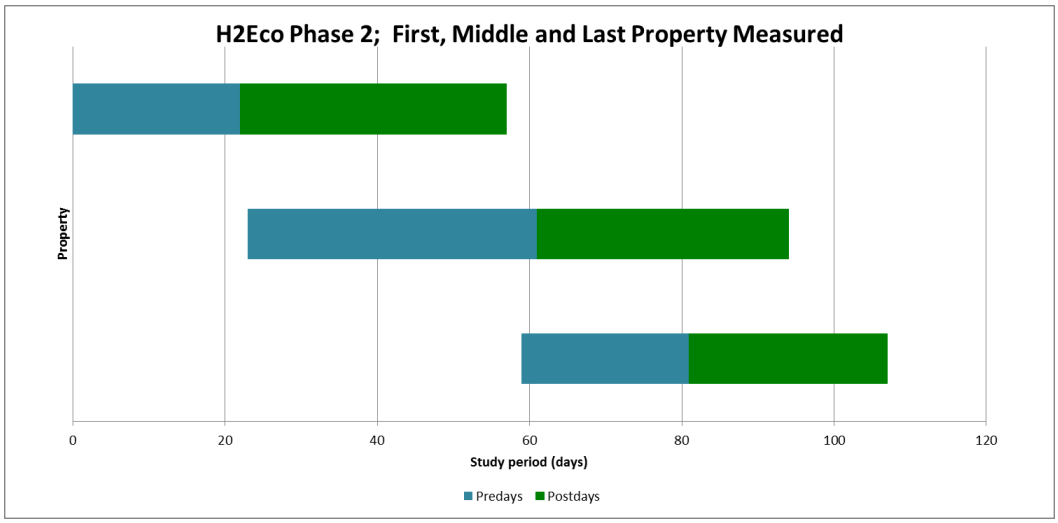
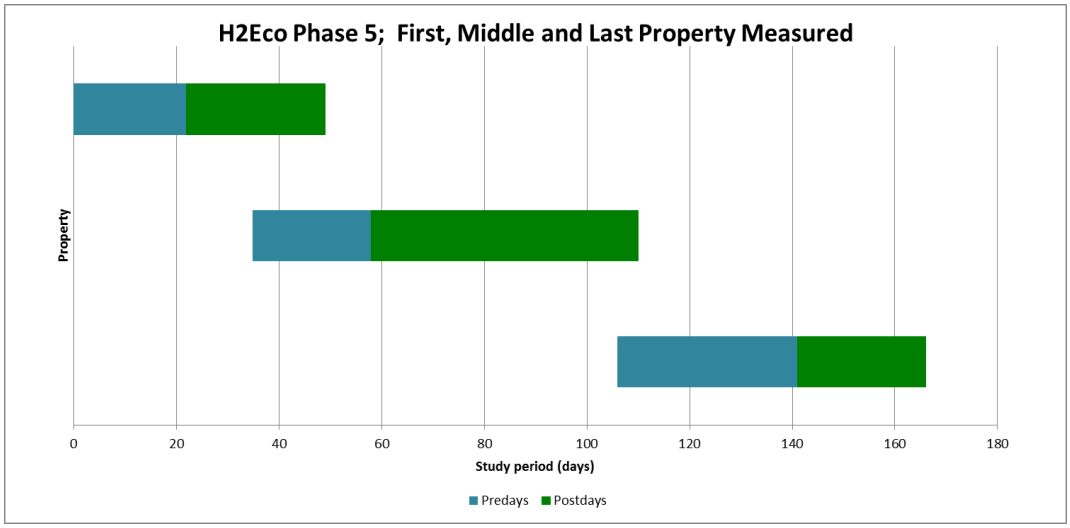
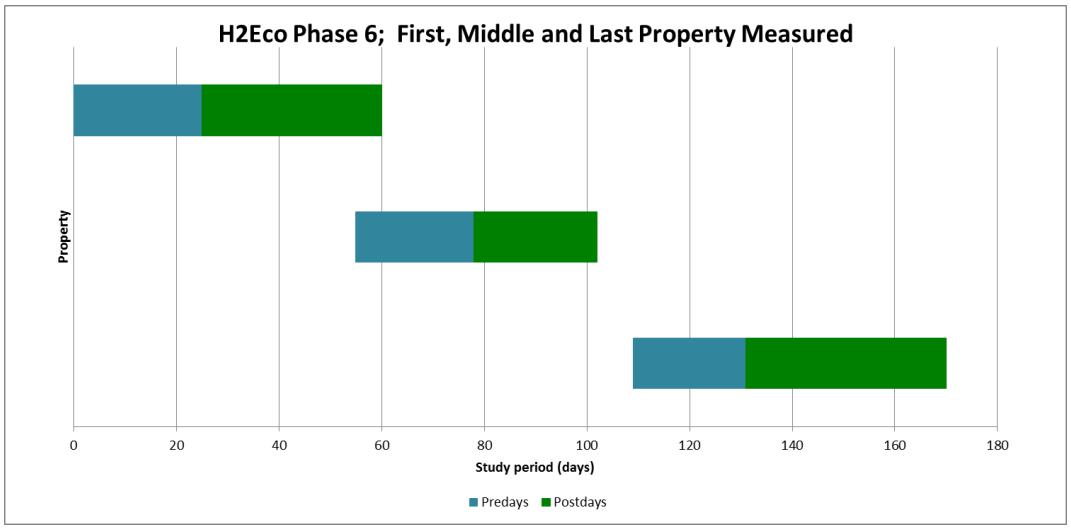
Appendix C Pre and Post measurement periods

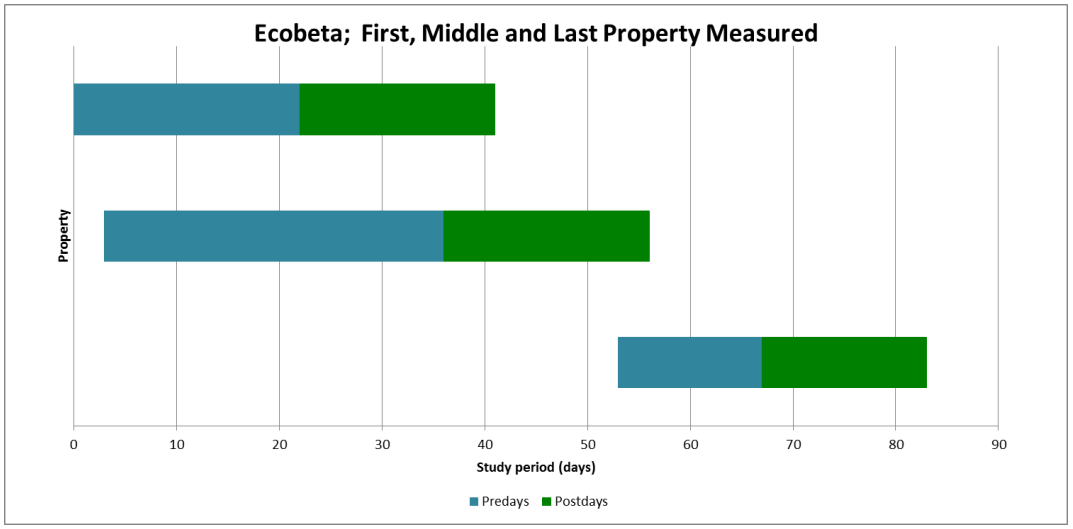
Below are the pre and post periods for first middle and last property within each study. The blue bar is the pre and the green the post period.

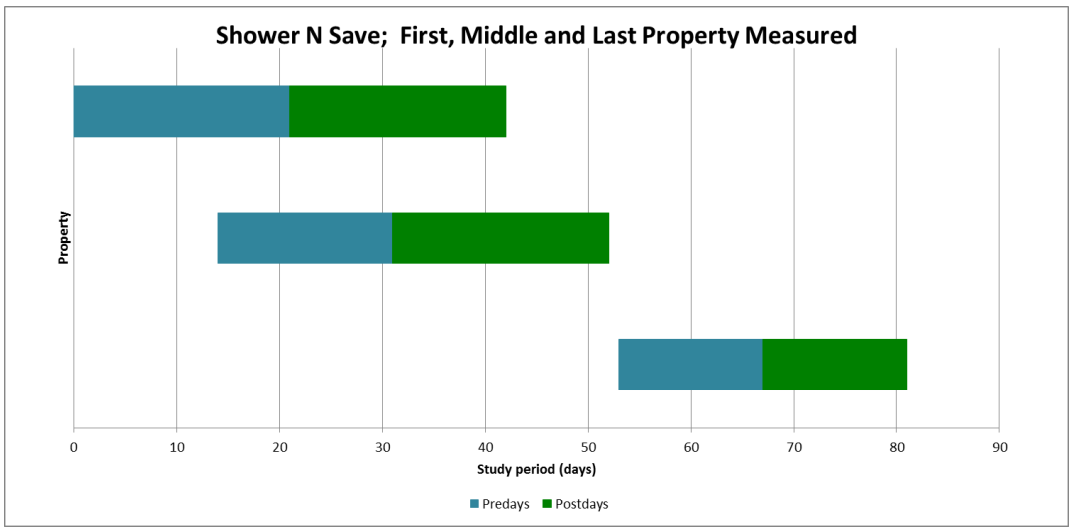












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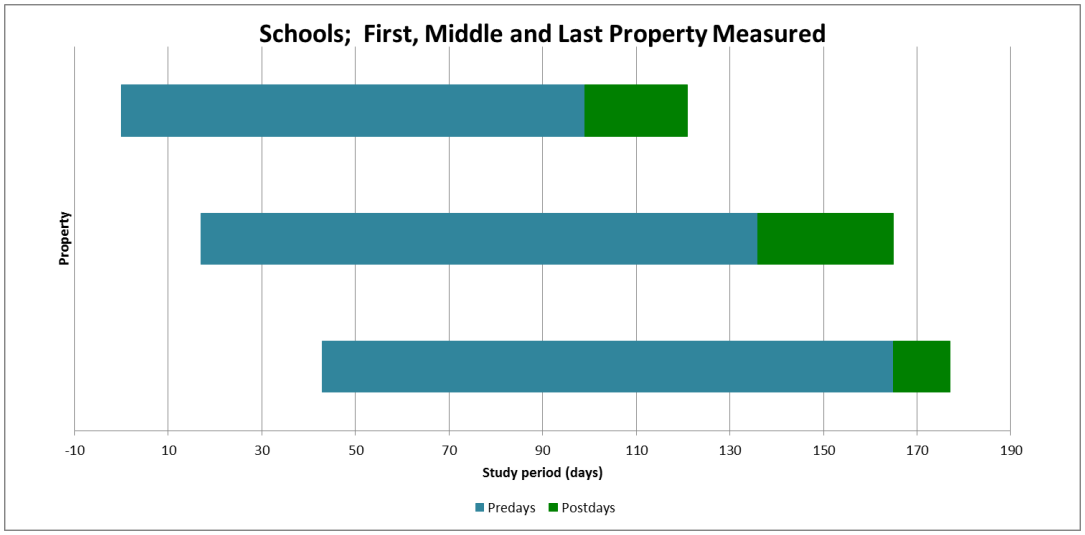
Schools; First, Middle and Last Property Measured
Property
-10
10
30
50
70
90
110
130
150
170
190
Study period (days)
Predays
Postdays

Appendix D Control PCC consumptions for Pre/Post study periods

The PCC has been analysed in 5 separate ways for each study.

1. Using a single typical pre and post period applied to all ESW DCM properties.
2. Using a single typical pre and post period applied to Essex DCM properties only.
3. Using individual property pre and post periods for every property within each study applied to all ESW DCM properties.
4. Using individual property pre and post periods for every property within each study applied to all Essex DCM properties.
5. Using a single typical pre and post period applied to all ESW DCM properties broken down into top level Acorn categories (1 to 5).

All ESW DCM using a single typical Pre and Post period.

The 3 mean dates for each study are the means of all the start, audit and end dates for each study.

Study	Mean Dates	Mean Precons	Mean Postcons	Diff	90% CI		Stat Sig
H2Eco Ph1	20/1/2008 22/2/2008 16/3/2008	152.3	149.0	3.3	1.3	5.2	Yes
H2Eco Ph2	30/6/2008 2/8/2008 30/8/2008	157.5	158.0	-0.5	-2.7	1.6	No
H2Eco Ph5	1/12/2010 4/01/2011 12/2/2011	147.2	149.2	-2.0	-3.9	0.0	Borderline
H2Eco Ph6	7/09/2011 2/10/2011 6/11/2011	148.0	151.3	-3.4	-5.6	-1.1	Yes
Ecobeta Study	30/04/2007 24/5/2007 16/6/2007	159.9	158.2	1.8	-0.5	4.0	No
Shower N Save	29/10/2011 15/11/2011 02/12/2011	152.2	150.4	1.8	-1.3	4.9	No

Using this method only H2Eco Ph1 and Ph 6 returned statistically significant changes from pre to post study periods.

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DCM Essex Properties only using a single typical Pre and Post period.

Study	Mean Dates	Mean Precons	Mean Postcons	Diff	90% CI		Stat Sig
H2Eco Ph1	20/1/2008 22/2/2008 16/3/2008	153.4	152.7	0.8	-1.3	2.8	No
H2Eco Ph2	30/6/2008 2/8/2008 30/8/2008	161.9	162.1	-0.19	-3.0	2.6	No
H2Eco Ph5	1/12/2010 4/01/2011 12/2/2011	141.2	146.6	-5.4	-7.5	-3.43	Yes
H2Eco Ph6	7/09/2011 2/10/2011 6/11/2011	150.9	158.9	-8.0	-10.6	-5.3	Yes
Ecobeta Study	30/04/2007 24/5/2007 16/6/2007	166.7	163.8	2.9	0.05	5.7	Borderline
Shower N Save	29/10/2011 15/11/2011 02/12/2011	159.6	158.5	1.1	-2.7	5.0	No

Using this method only H2Eco Ph5 and Ph 6 returned statistically significant changes from pre to post study periods.

All ESW DCM (Essex and Suffolk) using Individual Property Pre/Post periods as control calculation.

The PCC values have been calculated for every individual property's pre and post period and the values aggregated up to a mean for each study group.

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Study	Mean Precons	Mean Postcons	Diff	90% CI		Stat Sig
H2Eco Ph1	152.1	149.8	2.3	2.1	2.5	Yes
H2Eco Ph2	157.6	157.4	0.2	0.0	0.4	No
H2Eco Ph5	147.8	148.0	-0.2	-0.4	0.0	No
H2Eco Ph6	150.7	149.9	0.8	0.6	1.0	Yes
Ecobeta Study	159.4	158.8	0.6	-0.5	4.0	No
Shower N Save	150.4	148.7	1.7	1.0	2.4	Yes

Using this method H2Eco Ph 1, H2Eco Ph 6 and Shower N Save returned statistical significant consumption adjustment numbers and in all three cases the adjustment numbers are very small.

DCM Essex Properties only using Individual Property Pre/Post periods ass control calculation.

Study	Mean Precons	Mean Postcons	Diff	90% CI		Stat Sig
H2Eco Ph1	153.4	153.5	-0.1	-0.2	0	No
H2Eco Ph2	161.9	161.3	0.6	0.4	0.8	No
H2Eco Ph5	143.3	144.4	-1.1	-1.3	-0.9	Yes
H2Eco Ph6	154.7	155.7	-1.0	-1.3	-0.9	Yes
Ecobeta Study	166.7	165.2	1.5	1.2	1.8	Yes
Shower N Save	158.0	155.2	2.8	1.9	3.7	Yes

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Using this method all studies except H2Eco Ph 1 returned statistical significant consumption adjustment numbers but again in all cases the adjustment numbers are small.

Acorn breakdown of the DCM has been calculated and inspected. The results are shown in the table below.

Study	Acorn Top	Mean Precons	Mean Postcons	Diff	90% CI		Stat Sig
H2Eco Ph1	1	145.9	143.7	2.23	-0.65	5.11	No
	2	169.9	159.0	10.9	1.50	20.30	Borderline
	3	148.3	147.8	0.51	-2.54	3.55	No
	4	161.1	157.0	4.1	-0.57	8.70	No
	5	141.6	129.9	11.72	6.11	17.33	Yes
Study	Acorn Top	Mean Precons	Mean Postcons	Diff	90% CI		Stat Sig
H2Eco Ph2	1	149.7	146.3	3.44	0.34	6.54	Borderline
	2	197.1	198.0	-0.94	-15.34	13.46	No
	3	159.5	160.8	-1.34	-4.96	2.27	No
	4	158.2	160.7	-2.56	-6.85	1.72	No
	5	142.4	144.6	-2.26	-7.50	2.97	No
H2Eco Ph5	1	150.7	148.4	2.3	-1.27	5.88	No
	2	121.0	133.7	-12.66	-18.71	-6.61	Yes
	3	147.3	148.5	-1.19	-3.58	1.19	No
	4	153.0	156.0	-3.00	-8.33	2.32	No

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	5	130.9	143.0	-12.11	-16.9	-7.3	Yes
H2Eco Ph6	1	151.8	156.7	-4.9	-9.1	-0.68	Borderline
	2	141.2	145.0	-3.9	-13.5	5.9	No
	3	150.9	154.8	-3.9	-7.2	-0.50	Borderline
	4	140.0	141.5	-1.5	-6.4	3.4	No
	5	146.9	149.7	-2.85	-12.72	7.03	No

Study	Acorn Top	Mean Precons	Mean Postcons	Diff	90% CI		Stat Sig
Ecobeta	1	157.2	152.7	4.49	-0.27	9.25	No
	2	204.0	174.7	29.7	8.0	51.4	Yes
	3	158.6	160.5	-1.94	-5.28	1.40	No
	4	161.3	159.6	1.65	-2.80	6.10	No
	5	131.8	135.2	-3.46	-9.23	2.31	No

Taking each study in turn.

In H2Eco Ph1 only Acorn 5 returned a statistically significant change and the DCM has only 5% in Acorn 5 which comprises less than 20 properties. Also in this study Acorn 5 comprises less than 10% of the study group as a whole. These number are too low to provide sufficient confidence that the results are reliable.

In H2Eco Ph2 there were not any Acorn levels which returned a statistically significant change in consumption.

In H2Eco Ph 5 Acorn level 2 and 5 returned statistically significant results however the reliability of this result has to be questioned because the DCM contains less than 20 properties in each of these categories. Even if the decision to rely on the results was made H2Eco Ph 5 only contains 2% of the study group in these categories.

In H2Eco Ph6 there were not any Acorn levels which returned a statistically significant change in consumption.

In the Ecobeta study only Acorn 2 returned a statistically significant change and the DCM has only 6% in Acorn 2 which comprises less than 20 properties. Also in this study Acorn 2 comprises less than 10% of the study group as a whole. These number are too low to provide sufficient confidence that the results are reliable.

Shower N Save comprises only 84 properties not a sufficiently large to to attempt to categorise down further.

The likelihood of achieving statistically significance results are improved in two ways. Increasing consistency of recorded measurements and increasing the sample size. Daily household water use is erratic so there is little opportunity to influence the consistency of measurement. The above results indicate that the DCM currently used by ESW is not sufficiently large to allow meaningful breakdown into Acorn categories. It cannot be used to reliably calculate consumption adjustment numbers for water efficiency trial periods.

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