COSMOS

Cultivate resilient smart Objects for Sustainable city application

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D7.4.3 – Smart heat and electricity management: Evaluation and recommendations (Y3 functionality)

WP7: Use cases Adaptation, Integration and Experimentation

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1. Executive Summary

The final evaluation and recommendations of COSMOS technology as applied to smart heat and electricity management show that there are no major requirements missing as compared to the deliverable D2.2.3 which are the final requirements for the COSMOS project.

There was a further application of COSMOS technology to humidity and damp detection with an application of early warning / prediction of dangerous damp for Camden residents. Using connected devices meant that triggers can be configured to alert specialist interventions by Camden Council and create a body of evidence to inform improvements in ventilation and wall treatments.

Throughout the project there has been a question about resident's willingness and ability to interact with technology. In particular, where new technical paradigms such as Internet of Things (IoT) challenge trust yet aid users with very easy, if not passive user interfaces. In this deliverable we conducted primary research on attitudes and ability to inform how technology that has been developed within COSMOS should be applied.

The IoT attitudes survey showed that the less comfortable users are with technology, the more they would like to exert manual control, even if the automation is highly intelligent and will deliver better results. There is a stronger trust in technology when there is a higher familiarity with information and communication technology, yet there was still a desire for some level of manual control within the system.

Further work should be done to research the social trust element of IoT. For instance, there was not an opportunity to look at "plan sharing" between households to see if trust levels would be greater if they were drawn from real people rather than algorithms. It is a hypothesis from the work in the Playbook that trust levels would be higher for automation rules that are traceable to friends, neighbours or family – even more than from an expert.

Major sections that were added from the previous release of the document is Section 8 covering surveys and qualitative research with end Users of involved in the COSMOS scenarios.

2. Introduction

This deliverable focuses on re-evaluating the adoption of the COSMOS technologies in real-world Smart City cases. We will use the Use Case Scenarios formulated in Year 2 as the basis of our assessment. We will also re-evaluate the technologies by looking at their assessments from Year 1 and 2, and at their current consistency, correctness and completeness.

Once again, these measures can be expanded into a list of criteria with which we will evaluate each of the technologies in WP3-WP6. In our use of these measures, we will implement a cost versus benefit assessment when applied to specific Use Cases in each of the two COSMOS scenarios.

Finally, it is important to use what we identify in this deliverable to recommend what our next steps should be for Year 3, and where we should focus our efforts on, in terms of research activities and productivity.

In this Work Package deliverable, we will:

- Provide background material describing the current situation in each of the new Use Case Scenarios from Year 2, as well as the ones from Year 1;
- Define a clear set of evaluation criteria for any given technology;
- Re-identify the technologies used in COSMOS, particularly the ones implemented in Year 3 prototypes;
- Assess each of the technologies in WP3-WP6 against the aforementioned criteria;
- Evaluate each of the technologies in WP3-WP6 alongside the overall requirements;
- Make extended recommendations based on these evaluations.

The outcome of this deliverable is to evaluate the technologies developed in COSMOS in each of the Use Case Scenarios against a clear and complete set of criteria.

3. Methodology

We will follow the same methodology for evaluating the COSMOS technologies as we used in D7.4.2. the previous release of this document.

In order to thoroughly evaluate the COSMOS technologies and assess the benefits they provide in different domains, we must first clearly define a complete set of evaluation criteria. This set of criteria must look at all aspects of a given technology, and be able to be applied to specific Use Cases.

We will then collect and list all of the technologies used in COSMOS, which have been described in WP3-WP6, looking at the London Use Case Scenarios and evaluating how each of the technologies will be used. This is done in a very structured manner, using the criteria to test different aspects of the technologies.

Next, we will consider the requirements in D2.2.2 (requirements definition document for COSMOS) and assess whether the use of the technologies developed in COSMOS will meet with necessary standards and solve any corresponding issues. These are the Updated requirements from Year 2.

Finally, based on results from the evaluation of the technologies in each of the new Smart Heat Management Use Case Scenarios, we will recommend Next Steps to take in COSMOS. Using the costs and benefits we find the technologies provide in different domains, we can help to direct the research activities of the project.

4. Evaluation Criteria

Whereas Smart City policy research has developed models for themes, issues and actions in developing a Smart City, very little research has been aimed at an operational level. In this section, we develop models that can be used for the implementation of IoT within a Smart City context.

In this deliverable, we reiterate the criteria that we use to evaluate the COSMOS technologies: the same evaluation criteria that were used in the D7.4.1 deliverable.

In order to properly assess the efficacy of the technologies used in COSMOS and their applications to the different Use Case Scenarios, we need to test them against a set of criteria. This ensures that each evaluation is fair and comparable.

It is important that these criteria capture the key measures for evaluating technology: consistency, correctness and completeness. We take consistency to mean how technically feasible, reliable and extendible the technology is, correctness to mean whether it satisfies the problem at hand and how convincingly it does so, and completeness to mean whether it is actually acceptable to implement such a technology, weighing its pros against its cons.

When looking at these measures, we realised that they can be broken down further into fundamentals, and grouped into four main criteria blocks: functionality, construction, realisability and impact.

1. **Functionality**
    a. *Satisfaction*.

        This concerns the extent to which the designed product satisfies requirements.

        Does the technology solve the problem? Is it a direct or indirect solution? Does it solve the problem completely or only partially?

    b. *Ease of use*.

        This concerns the ease of use for the Users, e.g. Operators, Application Engineers and residential End Users.

        Is it easy to design, implement and maintain? What programming languages are required, if any, and how well-known are they? Are some libraries, if any, required and how accessible are they? Does it require specialised Operators or Application Designers?

    c. *Reusability*.

        The extent to which the product can be used in other situations. This includes scalability and the ability to be used in (dis)similar contexts.

        How extendible is this technology? What sort of scale can it be rolled out to? Can it be applied to any other COSMOS components? How generalisable is it, or is it extremely specific/custom?

2. **Construction**
    a. *Structuring*.

        This concerns the partitioning of the product in logical or physical components.

What architecture is used? How complex is the system? How do the different components in the technology communicate with each other, and how efficiently do they do so?

b. *Convincingness*.

This concerns the evidence that the construction will work and has the defined functionality (empirical proof/statistical argument).

How well-known is this technology? What sort of research has to be done before design and implementation can take place? Has it been used in another COSMOS component? What is the likelihood of the problem being solved by using this technology as a solution?

3. **Realisability**

a. *Technical realisability.*

This concerns the level of certainty that it is technically possible to produce the technology.

What technical requirements are there? How difficult would it be to implement this technology? Do the technical components that make up the system's architecture link well together?

b. *Economical realisability.*

This concerns the business case for the technology.

Is the application of this technology financially feasible? Can the cost be covered by scalability and, if so, what sort of volumes are we looking at? Do the benefits outweigh the costs? Is the technology justifiable, or is there a more cost-effective solution that satisfies the problem?

4. **Impact**

a. *Risks.*

Risks during development or use stages.

Does the technology introduce new problems? Are there any privacy or security issues inherent to this technology? Are there authorisation restrictions between components? Are there any risks that could end up affecting the End Users through the applications?

5. Technology

A technology is the realisation of a function in the Internet of Thing's Architectural Reference Model. This includes physical devices, platforms, services and analytics, all of which are used to solve certain problems or add particular functionality to an IoT system.

COSMOS aims to build a smart system that uses Things in the space of IoT to solve the problems that cities currently experience. The two Use Case Scenarios that we will focus on are Heating Networks in the London Borough of Camden and the Bus System in Madrid. In order to solve issues that arise in the two Scenarios, we developed certain technologies in WP3-WP6. These technologies, when combined, produce the overall COSMOS system, ranging from hardware to software, and from servers to sensors. Each of the technologies mentioned in this section fulfils a specific role and has a purpose in COSMOS.

This section provides us with a clear list of the technologies used in COSMOS (Year 2), described fully in WP3-WP6, and whose applicability is described in the next section:

(WP3) D3.2.1: End-to-end Security and Privacy

- Privelets
- Node-RED Security

(WP4) D4.2.1: Information and Data Lifecycle Management

- Integration with Analytics Framework

(WP5) D5.1.1: Decentralised and Autonomous Things Management

- The Planner
- Social Analysis
- Network Runtime Adaptability Module

(WP6) D6.1.1: Reliable and Smart Network of Things

- Inference/Prediction Functional Component
- Pre-processing Functional Component
- Event (Pattern) Detection Functional Component

6. Application Use Cases

This deliverable provides an update to the scenarios from Years 1, 2 and 3, with a final review of the Use Cases in order to make a full and operational system. Detail of the scenarios can be found in D7.1.3 – Use Case Definitions.

6.1 Camden Scenario

6.1.1. Capital Planning / Energy Performance

Use Case: Capital Planning/Energy Performance and Commissioning and Quality Assurance
ID: 1
Brief Description: The EnergyHive system in each building enables Capital Planning/Senior Energy Performance Officer to perform a more rigorous cost/benefit analysis of suggested programs or technology installations. The system provides accurate information as to the carbon/monetary saving of an implementation.

6.1.2. Minimising CO_2 Emissions

Use Case: Minimising $C0_2$ Emissions
ID: 2
Brief Description: An effective way to minimise carbon is to give more weighting to processes with lower $C0_2$ levels whilst maintaining the demand. The interconnected IoT-based system using an energy platform will make possible effective management of the energy supply in order to minimise $C0_2$ emissions. With minimal input by the resident or site staff, the system will predict the estate's heat in half-hourly intervals and manage the CHP and boiler accordingly.

6.1.3. Minimising Demand

Use Case: Minimising Demand
ID: 3
Brief Description: Another method of reducing $C0_2$ emissions is to minimise the demand for Heat Energy. This is possible through the current IoT platform, namely EnergyHive (designed by Hildebrand). The EnergyHive system will use smart meters to report real-time energy consumption information, both automatically and remotely. The system, with support from a council Sustainability Officer, assists the user in setting a heating schedule in accordance with their budget. The purpose is to make users aware of the cost of heating, with the Sustainability Officer being able to identify and support users who are particularly high consumers and, therefore, at risk of fuel debt. Similarly, Council Officers will be able to identify particularly low use, which may indicate a health risk or non-occupancy.

6.1.4. Heating Control

Use Case: Heating Control
ID: 5
Brief Description: The EnergyHive system is measuring the temperature of the properties where it is installed and has the ability to control the delivery of heat through a valve. A new tablet has been deployed within the property that allows for a set point and schedule to be entered. Feedback from users has been that they would like the system to automatically help them set a programme and manage efficiencies on an ongoing basis, for instance: detection of whether or not they are at home; using the weather forecast to help with program and supply-side management when the solar thermal is available for use. The tablet is a COSMOS-compatible device and it can act locally to run case-based reasoning in an efficient manner.

6.1.5. Building Performance Management

Use Case: Building Performance Management
ID: 6
Brief Description: The boiler systems within buildings have master programmers and temperature settings that are controlled by a Trend boiler control system. There are also verification instruments installed within buildings to measure the effects of the boiler control; they can provide feedback to inform the run-time commands to the boiler control as well. A more granular view of the energy demand, including trade-offs with electricity usage, is desired so that individual residential premises are getting higher comfort while balancing the energy input.

6.1.6. Identification of Opportunities

Use Case: Identification of Opportunities
ID: 7
Brief Description: The EnergyHive system running in planning mode can use machine learning to suggest opportunities for efficiency. This is largely an unsupervised learning exercise where cause and effect models can be run with comparisons to other like buildings or similar conditions that have been observed. Using machine learning, identify where energy savings opportunities exist. This will help Sustainability Officers to identify projects with sound business cases, with both $C0_2$ emissions savings and energy reduction benefits, which can then be submitted for formal approval.

6.1.7. Damp/Condensation Monitoring

Use Case: Damp/Condensation Monitoring
ID: 8
Brief Description: The aim is to help residents to identify and reduce/eliminate damp, where it

exists: humidity sensors monitor condensation levels and identify where damp is best detected; temperature sensors measure how the temperature of the properties affects damp; and window open/close sensors demonstrate the extent to which the residents are ventilating their properties.

6.2 Residents' Health and Safety

Camden currently provides a well-being service to their residents called 'WISH Plus'. This provides a way for Camden residents to improve their health and well-being by using a range of Warmth, Income, Safety and Health services, all under one roof.

Visits to residents conducted in preparation for the COSMOS project have provided additional opportunities to make referrals to the WISH Plus team.

The Equality Impact Assessment (EIA) undertaken for the Heat Metering project has been used to determine the profile of residents who will potentially be using the COSMOS services, and has been taken into consideration when selecting the sample of volunteers for the Pilot.

Risk Assessments were also conducted for residents taking part in the Pilot (see Appendix A). The assessments concluded that any potential risks arising from the Pilot can be controlled or mitigated by the implementation of the measures described in the assessments.

Improving the health and welfare of city dwellers and making warmth affordable and manageable, especially for those at risk of fuel poverty and the related illnesses that poor or unaffordable heating causes, are all at the heart of this Use Case Scenario. In addition, the Pilot will be run in accordance with Camden's stringent corporate Health and Safety guidelines, valuing its diversity ethos and strategic objectives as set out in the Camden Plan.

6.3 Technologies

6.3.1.1. End-to-End Security and Privacy

The Privelets component is responsible for the authentication process on top of any kind of VE2VE communication in order to avoid possible VE impersonation. VE2VE communication includes:

- Accessing a VE's IoT service from another VE;
- Decentralised discovery;
- Recommendation service between VEs;
- Information (e.g. Experience) Sharing.

By preventing VEs impersonation, the Privelets component gives added value to the Trust and Reputation model introduced in the context of WP5, while by ignoring repetitive requests, it enables the VEs to protect themselves against wasting valuable computational resources caused by malicious attacks.

The Privelets component's source code is developed in Java programming language and depends on Jetty Server, Apache-Jena, Pellet-Jena, JSON-simple and other Java libraries. The prototype also relies on FreeLan, an open source software, in order to establish the COSMOS VPN and connect it with the VEs.

Privelets satisfy the requirement of adding an authentication layer to the hardware in a simple yet robust way. The programming language and associated technologies are easy to use and widely well-known. It is easy to design, implement and, most importantly, maintain.

Furthermore, an additional benefit of using the object store technology is that it ties in well with the COSMOS other elements, as they are all built with the other components in mind.

In terms of construction, they are very straightforward and intuitive to set up in the system. Their efficacy and reliability, however, remains to be seen, as this will be proven during larger-scale prototypes later on in the project. This is important to note as simple testing may not show up all issues and/or limitations.

Technically speaking, it is relatively simple to use this technology in the scope of COSMOS. It could be argued that this is excessive, and merely to satisfy requirements. While it is true that this technology is fairly new and untested, and perhaps a more established technology could have been used to ensure efficacy, we might argue that the choice of using Privelets is fully justified as we are trying to build an innovative Smart City solution with advanced capabilities and functionalities.

There would need to be considerable management functionality around Privelets in order to really be able to use it in a commercial application, whereby additional security and integrity (key management, secure application of privileges, etc) are required and non-trivial to implement.

The visual tool (Node-Red) for wiring the Internet of Things is a platform-independent software framework that has been developed bearing in mind its usage not only in big servers or the cloud, but also in small, embedded computers such as the Raspberry PI, Arduino and similar others. Traditional IoT development can be very technical: access to the GPIO and other hardware modules requires skills in C or assembler, and output of data to web services or sending tweets and emails requires the use of complex APIs. Node-RED– takes care of the technicalities to allow focus to remain on the logic of the workflow. While most programming in Node-RED is done visually using pre-defined functions or 'nodes', any additional functionality can be added in JavaScript.

6.3.1.2. Information and Data Lifecycle Management

In COSMOS, we store historical data for VEs in object storage (based on OpenStack Swift) in a format that is amenable to access by Spark SQL for the purpose of analytics of the data. Our driver allows optimised access to this data. All COSMOS services that make use of historical data can benefit, including applications that use machine learning on historical data and applications that analyse or report on past behaviour or the activity of VEs.

The driver is used to help access data from the COSMOS storage system, and is tailored to suit the particular structure and implementation style of the object store. In terms of functionality, this driver is limited in one sense, as it is specifically designed to work with OpenStack Swift and Spark SQL, but it could potentially be used when developing the aforementioned technologies in Year 3.

Due to the fact that it is a driver just for data access, its structure and convincingness remains strong and intact. As it simple 'works', we have no reason to question its setup or ability to provide easy and cheap access to all of the data being stored in the COSMOS servers.

In terms of realisability, both technically and economically speaking, this technology is certainly feasible, as it provides us with exactly what we need while being lightweight and cheap. It should be noted however that the development costs of this technology would have to be higher than alternatives in order that it works with the current setup that COSMOS is using.

Once again, we have assessed the risks of this technology and concluded that there are no major concerns in using the driver to access the data from the object store.

6.3.1.3. Decentralised and Autonomous Things Management

As is stated in D5.1.1, the functional component that enables the VEs to use CBR is the Planner. The Planner will become part of the VEs during their registration time and will run locally. The main functionality of the Planner is to provide the VEs with the ability to react to problems. This uses a reasoning technique for finding the most appropriate solution to be applied based on similarities to previously encountered or experienced situations. This is a step towards the autonomy of the VEs, as depicted by the goals of Task 5.2 (Autonomous and Predictive Reasoning of Things).

The interaction metrics (Shares, Assists and Applauses) monitored by the Social Monitoring component of a VE are stored locally in the corresponding Followees Lists. These metrics are calculated in a distributed manner by the VEs on a per-VE basis, and are the main input for the services provided by the Social Analysis and Friends Management components. The social indexes of the several kinds of Friends are extracted from these metrics. These are the Trust Index, the Reputation Index, the Reliability Index and the Dependability Index. Since the social indexes will constantly change, it is important to take their evolution into consideration. Although a VE may have a low Reputation Index when we study a wide time-window, it may have a much greater Reputation Index when we study a smaller and more recent time-window. This means that the specific VE is improving, and this improvement should be evaluated fairly by the system and the community. For this reason, for each Followee in each Followees List, the timestamps (Unix time) and the evaluation of the last 3-10 interactions, for example, may be kept so that, when applying simple rules, the evolution of the indexes can be studied.

The Network Runtime Adaptability module is able to dynamically assign resources performing different activities within COSMOS architecture. In this sense, the key objective of this module is to control the resources usage of every single component. The monitoring of resources usage enables the optimisation and prioritisation of processes inside a VE. Besides this, the same functionality can be used in a multi-CPU environment for distributing the computational load, and thus minimising the risk of blocking processes.

These technologies allow the VEs to use the CBR technology autonomously so that decisions are made locally with the knowledge of a decentralised system. Although it does achieve an extremely powerful logic base, it is a complicated system to manoeuvre and needs to be designed with care and caution. Having said this, the concept behind this technology is extremely scalable, and can be extended to the Trust and Reputation models, as well as help integrate autonomy in other COSMOS components.

As the concepts introduced by these technologies are quite convoluted and highly theoretical, its convincingness unfortunately remains to be seen. The structuring of the Planner and the Social Monitoring components in the prototypes will be the pivotal point of assessment for this technology.

The gains from localising these technologies and attaining a decentralised autonomous system are clear. However, reality dictates that this technology could very well be technically insufficient in terms of reliability and consistency for the corresponding cost and effort.

As these technologies are most beneficial when integrated into the system locally, the added security risks are one of our concerns. Extra time and effort must be spent in WP3 to ensure that the hardware is encrypted and reliable. Furthermore, making decisions locally means that it is more difficult to see how the system is operating (although, on the other hand, it also allows the system to operate without internet connectivity). In this sense, the Trust and Reputation model becomes critical when moving from model to real life, because damage caused by malicious users could produce very relevant losses. Effectively, it is a trade-off between scalability and autonomy failures.

6.3.1.4. Reliable and Smart Network of Things

The Inference/Prediction component is responsible for analysing raw data in order to provide high-level knowledge which can be used for automated, proactive and intelligent applications. In this regard, we have implemented several pattern recognition algorithms on the Use Case Scenarios, such as different variants of Support Vector Machines (SVM) and Hidden Markov Models (HMM) for inferring high-level knowledge.

We have also explored several regression mechanisms for time series prediction of data for providing proactive solutions for Smart City applications. In this chapter, we briefly explain the architecture, interfaces and application of the component with the help of a Use Case Scenario.

Pre-Processing is a generic component, and different components such as inference/prediction FC and Event (Pattern) detection can use it according to their requirements. It involves several functions, ranging from simple data cleaning mechanisms to more sophisticated mechanisms, such as data aggregation or feature scaling.

The Event Detection component is intended to provide the functionality for the near real-time processing of data for Event detection, by providing a hybrid solution based on Complex Event Processing (CEP) and Machine Learning (ML) methods. CEP provides a distributed and scalable solution for analysing data stream in near a real-time manner, but it does not exploit historical data, and the manual setting of rules is a major drawback. Rules for CEP are static, and hence solutions provided by CEP are static as well. Though ML methods exploit historical data and provide more automatic solutions, they are unable to provide near real-time solutions, and scalability is a major issue. In our proposed solution, we exploit both approaches and combined them in order to provide a near real-time solution that is more context-aware, adaptive and exploits historical data.

All of the components developed in WP6 in Year 2 aim to bridge the gap between data and decisions by means of pre-processing, data aggregation, feature manipulation and, primarily, machine learning techniques. The ease of use of these components decreases as we work on more state-of-the-art statistical models and look to solve more complex problems. The big benefit of developing an array of tools and components to handle data from point of extraction to point of decision is that the technologies are highly reusable and extendable. A lot of the fundamentals from the Event Detection component and the Inference/Prediction component can be easily applied and integrated into other COSMOS components, such as the CBR Planner developed in WP5.

Once again, the structuring of these components ranges, becoming more challenging as we approach the more theoretical and experimental machine learning models. Similarly, in terms of convincingness, we do not have a well-established best method of modelling the data sets available to us. Once the prototypes for the Use Case Scenarios are fully up and running and are heavily relying on these components, we will see whether they are able to reliably and accurately provide useful predictions.

The benefits for the CEP are clear motivations for the development of these components. However, once again, we must look at the economical realisability of some of the more theoretical and experimental modelling components. The time and effort spent on developing these techniques could prove to be wasteful if the results are not impressive or that of a state-of-the-art technology. Fortunately, the version of CEP developed in COSMOS is able to run on simple devices, and hence goes beyond the capabilities of current technologies, both in terms of ease of use and target platforms. The improvement assessment provided by the more theoretical contributions will help in the identification of their further potential, as well as the number of domains that will be targeted.

Finally, we have assessed the risks of these predictive tools and evaluated whether they expose the COSMOS system too much, especially when dealing with vulnerable citizens in a Smart City. We have concluded that any risks seem to be minimal, due to the testing and positive results shown in WP6.

7. Requirements

In this section, we will evaluate the list of 106 requirements put together over the course of COSMOS that has been provided in the WP2 deliverables. We will assess our progress for each of the requirements according to the three main criteria: consistency, correctness and completeness. We aim to achieve all three criteria for each of the requirements, as this demonstrates that we have fully satisfied the needs of COSMOS.

The percentage number of requirements that meet these different levels of compliance is presented in the following table (Table 1) according to work done to date:

Table 1: Percentage number of requirements meeting different compliance levels.

Compliance Level	Number of Requirements	Percentage Number of Requirements
Fully met: consistent, correct and complete	71	68%
Mostly met: not consistent	4	4%
Mostly met: not correct	0	0%
Mostly met: not complete	19	18%
Partially met: only consistent	0	0%
Partially met: only correct	9	9%
Partially met: only complete	0	0%
Unmet	1	1%

Approximately two thirds of the requirements have been 'Fully Met' (are consistent, correct and complete) due to the design and implementation of the technologies in the Use Case Scenarios. As the Use Cases are so diverse and test the system so thoroughly, we find that satisfying the needs of the requirements are consistent, not only across both the London and Madrid systems, but also within these systems. The consistency of these technologies for all aspects of the Use Cases in each of the Scenarios has been noted in Section 5, and is verified in our evaluation of the requirements.

About 20% of the requirements have been 'Mostly Met' (are consistent and correct, but not yet complete), as the aforementioned technologies solve the issues that the requirements propose, and do so in a smart, efficient and scalable way. Furthermore, these technological solutions can and have been adapted to fit different aspects of COSMOS, and work well with all components in the system. The final criterion of completeness, however, has not been met because there are still parts of the requirement that have yet to be fulfilled.

Fewer than 10% of the requirements have only been 'Partially Met' (are correct, but not yet consistent or complete), which is a pleasing result at this stage of the process. These requirements have the potential to be met with the use of the aforementioned technologies. However, it is just the theory behind these technologies that lead us to believe that problems can be solved. In terms of ensuring that the evaluation criteria can be met across the board without any loopholes or errors, the requirements that fall into this category currently fall short.

The 1 requirement listed in the table below (Table 2) has been marked as ‘Unmet’ as there is not enough clear documentation on how and where it has been satisfied in the COSMOS project.

Table 2: Unique ID number and description of ‘Unmet’ requirements.

Unique ID	Description
245	COSMOS must support the creation of new applications through the creation of new GVEs or other mechanisms.

Group VEs (GVEs) have not been required by scenarios but could be useful in scaling solutions when multiple applications are actually running within the COSMOS system. The GVE concept lends itself well to applying a template to a number of virtual entities (VEs) that act as a class of entities.

8. Survey Research

Throughout Year 3, Camden Council and Hildebrand have hosted a series of engagement workshops with local Camden residents in order to inform the COSMOS project as a whole, and in particular to provide a local context for the two Camden Use Case Scenarios being implemented this year.

In the case of the Camden Scenario, potential end users of the COSMOS services are social housing residents belonging to a diverse community, with differing levels of understanding and/or acceptance of technology. Our aim has been to gain a more in-depth understanding of these differing attitudes to technology and, more specifically, smart heating systems, and how this might be affecting residents' health and welfare. We also wanted to give residents an opportunity to express their individual priorities and areas of concern when it comes to heating their homes, and how the COSMOS platform might be designed to satisfy the unique preferences of its end users more directly.

8.1 Resident Engagement Events

Table 3 (below) details events that Camden Council and Hildebrand have hosted during Year 3 in order to conduct survey research and engage with local Camden residents.

Table 3: Resident engagement events for Year 3

Activity	Date	Number of Respondents	Notes
Questionnaire Workshop	01/02/2016	7	Questionnaires designed to gauge residents' opinions on smart heating. Written information about COSMOS was also provided, as well as a verbal explanation of smart heating.
Questionnaire Workshop	02/02/2016	9	
Questionnaire Workshop	03/02/2016	7	
Questionnaire Workshop	25/02/2016	22	
Pilot Installations	18/04/2016 – 20/04/2016	9	Questionnaires given to residents participating in the Pilot.
Questionnaire Workshop for Sheltered Residents	29/04/2016	5	Workshops with sheltered residents to better understand how smart heating systems might be received by the elderly.
Questionnaire Workshop for Sheltered Residents	18/05/2016	15	

8.2 Survey Documents

Camden and Hildebrand developed a set of explicatory documents and questionnaires to be used in resident engagement workshops, including:

- a **Participant Information Sheet**;
- an **Informed Consent Form**;
- a **Participant Profile Questionnaire**;
- a **Smart Heating Explanation Script**; and
- a **Home Heating Questionnaire**.

This deliverable will evaluate residents' responses to the Participant Profile and Home Heating questionnaires (see Appendix A for complete versions of these tools).

8.3 Survey Results

Responses were collected from a total of 74 Camden residents. We have identified a number of significant correlations between the background of the participants, their priorities when thinking about heating their homes, the level of automation of their ideal heating system and their comfort level using technology.

Question 10 of the Home Heating Questionnaire asked participants whether they thought their heat meter helps them to save energy. Broadly, respondents stated that they do not find their heat meters helpful – only 41% reported them as being useful. This response was largely present across all respondent segments (see Figures 1 and 2).

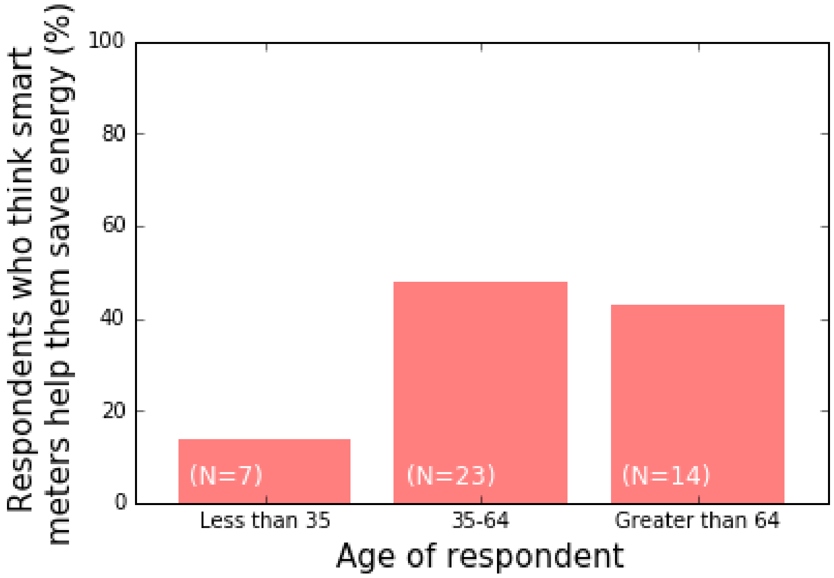

Figure 1: Graph comparing age with attitude towards smart heat meters.

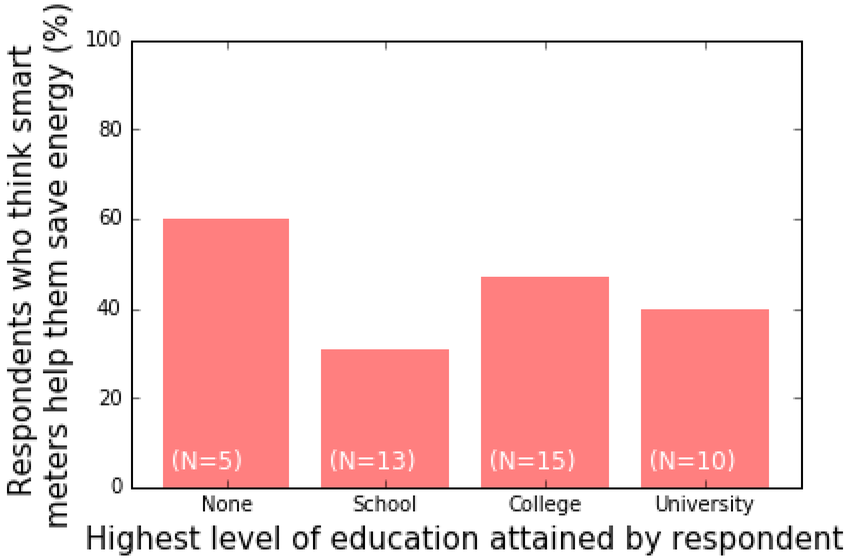

Figure 2: Graph comparing level of education with attitude towards smart heat meters.

Even respondents who considered themselves ‘comfortable’ or ‘very comfortable’ using technology did not report increased belief that smart meters help them save energy: only 50% (15) of such respondents reported that they believed smart meters help them to save energy.

In Question 11, respondents were then asked to describe their ideal heating control. Respondents showed a preference for manual heating systems over automatic ones: 52% (33) of residents asked stated that some form of manual heating system was their ideal.

There is a great distinction amongst different segments of respondents, however. Residents with higher levels of education, who were younger, or who reported higher levels of technical comfort, all were more likely to report some form of automated heating system as their ideal. This is shown in Figures 9 to 11, where we take automated heating to be either fully or partially automated heating.

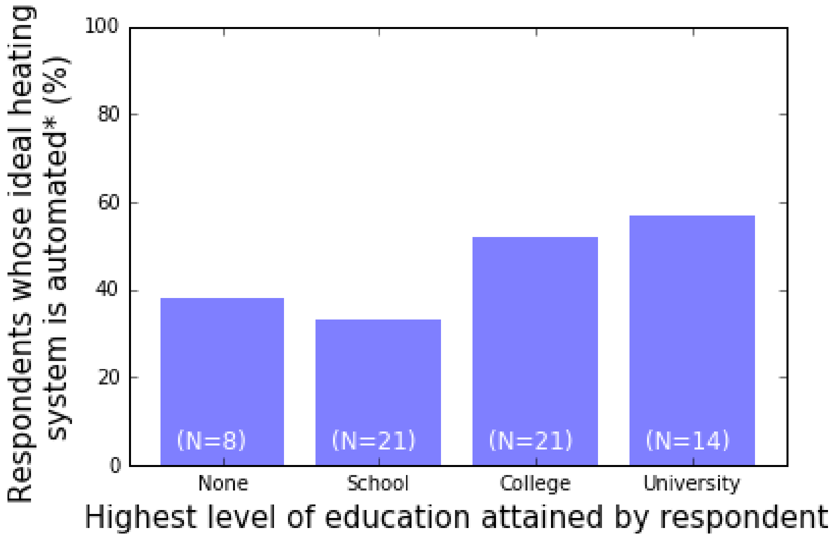

Figure 3: Graph comparing level of education with preferred level of heating system automation.

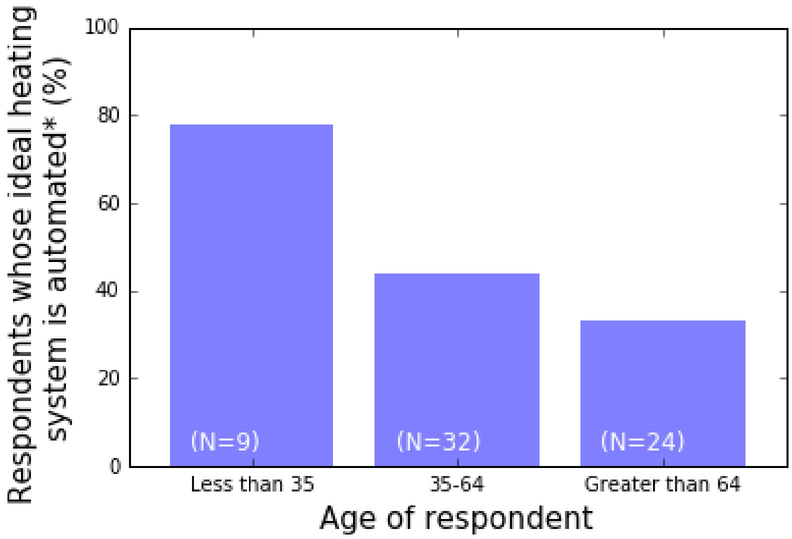

Figure 4: Graph comparing age with preferred level of heating system automation.

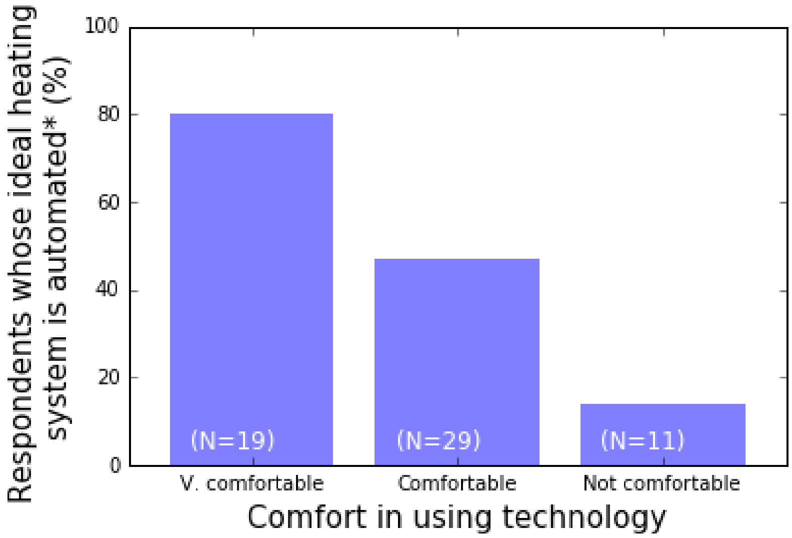

Figure 5: Graph comparing comfort in using technology with preferred level of heating system automation.

In spite of this majority preference for a manual heating system and a broad belief that smart meters do not help save energy, 78% (52) of respondents stated that they were interested in at least one of the following smart heating system controls:

- a system that learns heating preferences;
- a system that can be remote controlled;
- a system that automatically adjusts according to external weather conditions,

and only 13% (9) explicitly rejected each option.

Of those who stated that they would want at least one of the options, 98% (45) preferred a system that either learned heating preferences or automatically adjusted heating based on weather.

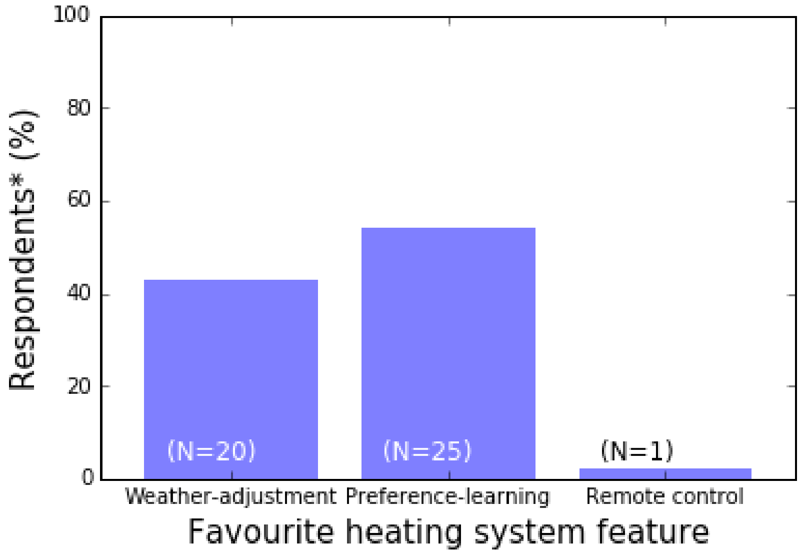

Figure 6: Graph showing the number of respondents that preferred each heating feature.

This shows a significant gap between residents' perceived and actual levels of understanding about smart heating systems and the controls that smart heat meters can offer them.

We also wanted to see how far a resident's preference for an automated, smart heating system might be affected by their priorities when thinking about heating their homes, their age and background, and their comfort level using technology.

Question 2 of the Home Heating Questionnaire asked respondents to consider how important various statements were to them when heating their homes. The primary features of importance (measured by the percentage of respondents that stated they were either extremely important or important), were stated to be:

- keeping the home warm and comfortable (93%);
- having a heating system that operates correctly (88%);
- keeping the home healthy (84%); and
- keeping heating within budget (83%).

Significantly, respondents whose ideal heating system would be somehow automated viewed all of these features as being slightly less important than respondents whose ideal heating system would be fully manual (see Figure 7).

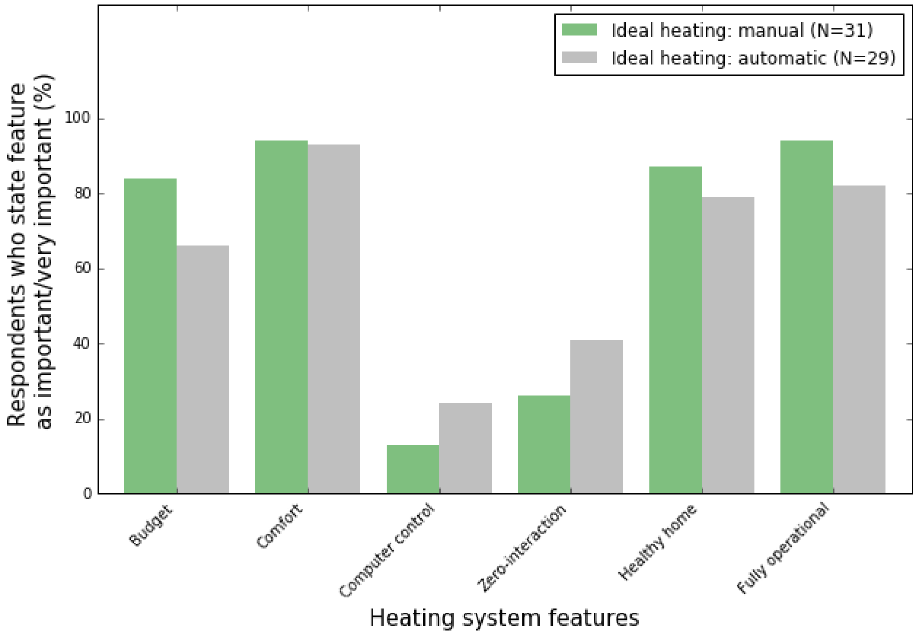

Figure 7: Graph comparing the importance of certain heating system features with

In particular, only 66% of respondents interested in an automatic heating system reported budget as being important. This contrasts with respondents who stated a preference for a manual system, of which 85% consider budget to be an important feature.

We also determined a strong relationship between age and the importance given to keeping heating within budget. Analysing budget by age segment, we found that 91% of people aged under 35 consider budget to be an important issue, compared with 76% of people aged over 64 (see Figure 8).

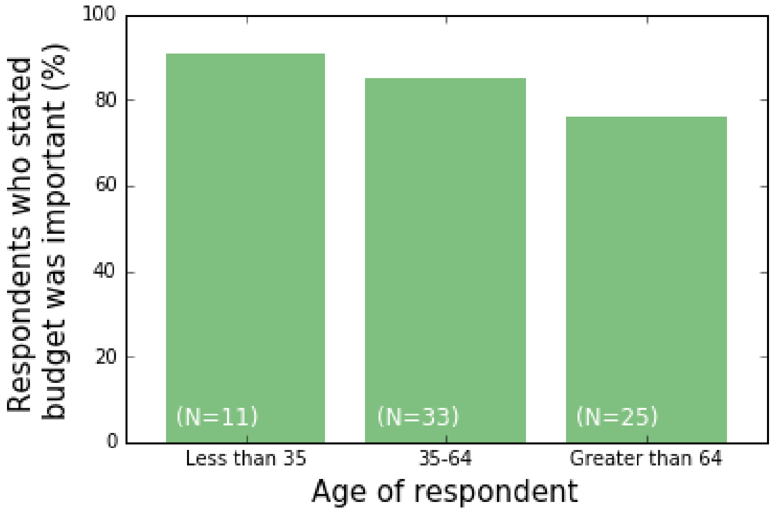

Figure 8: Graph comparing the importance of keeping heating within budget to respondents with their age.

There was no particular correlation between the other profile segments and importance placed upon reasons why a respondent might want to control their energy use.

We also studied those responses to the options provided in Question 2 of the Home Heating Questionnaire that most relate to IoT features:

- I want to control my heating from a mobile/computer;

- I don't want to interact with my heating controls (I prefer fully automated controls); and
- I want my heating system to operate correctly.

Younger people were more likely to be interested in the ability to control heating from some computer system; 45% of those aged under 35 report an interest in this feature, as compared with only 20% of people aged over 64.

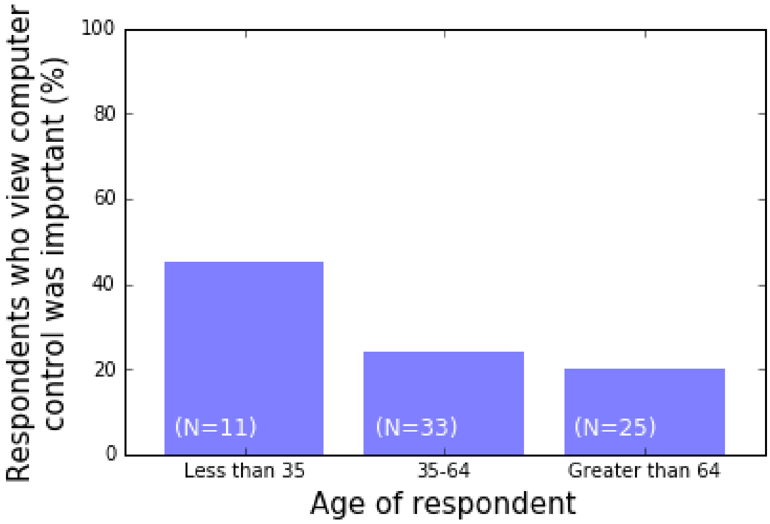

Figure 9: Graph comparing age with the importance given to computer controls.

More educated people also place a greater importance on the ability to control a heating system using a computer. 7% of respondents that did not complete education beyond school report this feature as being important, compared with 41% of respondents who stated their highest education as either college- or university-level.

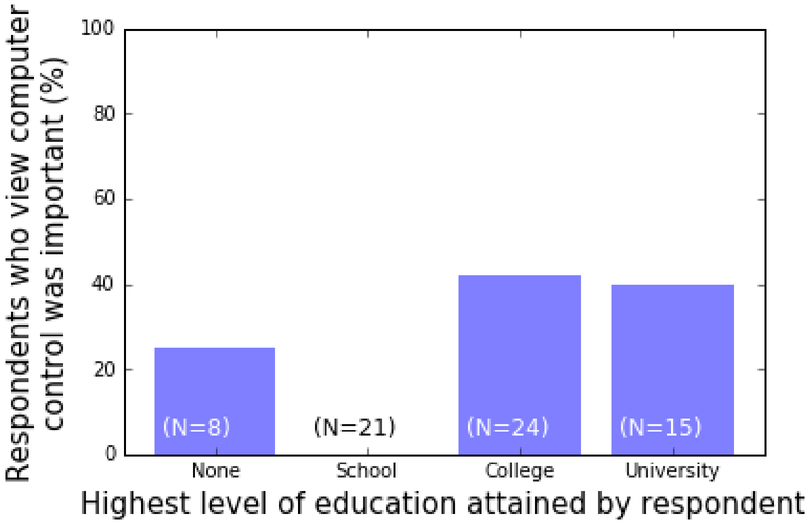

Figure 10: Graph comparing level of education with the importance given to computer controls.

We also considered the correlation in response to self-reported comfort with technology. Respondents who consider themselves not at all comfortable with technology are more likely to want a system that is fully operational (100%), and they are less likely to want to operate their system using a computer (0%) or that requires no interaction (20%).

This contrasts greatly with respondents who consider themselves very comfortable with technology. They are more likely to want to use computer control (64%) and not require interaction (45%). They are all less strict in the demand that a system be fully operational (82%), as demonstrated in Figure 11 below.

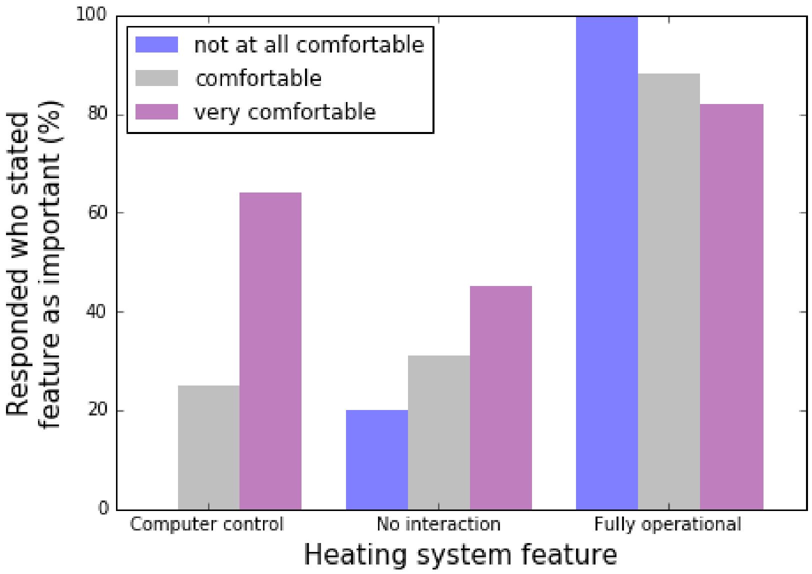

Figure 11: Graph comparing heating system features with comfort levels using technology.

8.4 Online Survey

Going beyond the resident engagement events that took place, we created an online questionnaire (see Appendix B) that was open to the public. In total, 53 responses were collected, through which we were able to identify a number of significant requirements and proposals for the further development of the COSMOS smart heating application.

The first two questions were mainly focused on the technological background of the respondents. As it can be seen in the following graph, about 75% of the respondents feel (very) comfortable with technology, a percentage that is in agreement with the results provided by the results from the resident engagement events.

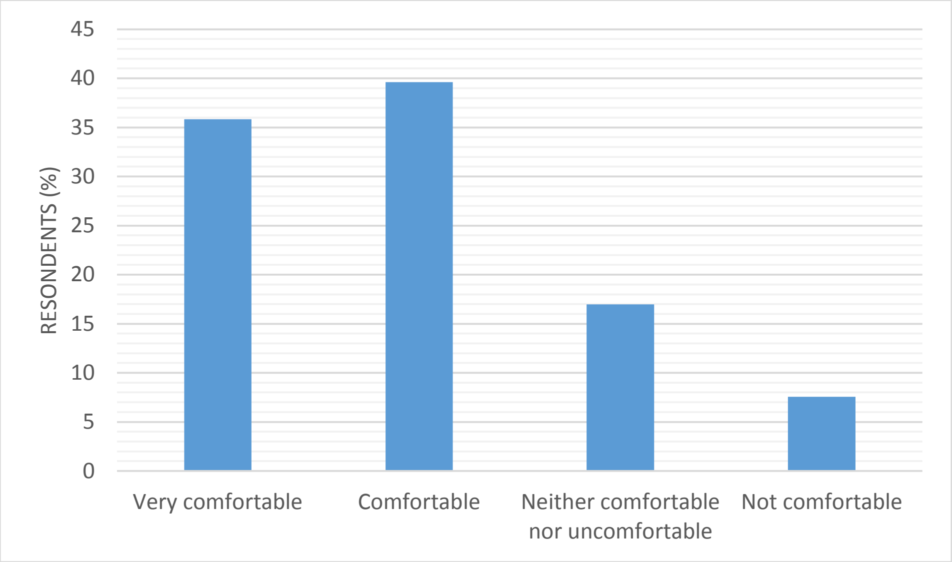

Figure 12: Graph presenting how comfortable the respondents feel using new technology.

The next chart pie shows that about 55% of the respondents have smart devices (smart phone or tablet), whereas 45% of them do not. The smart devices could be used for the smart home application.

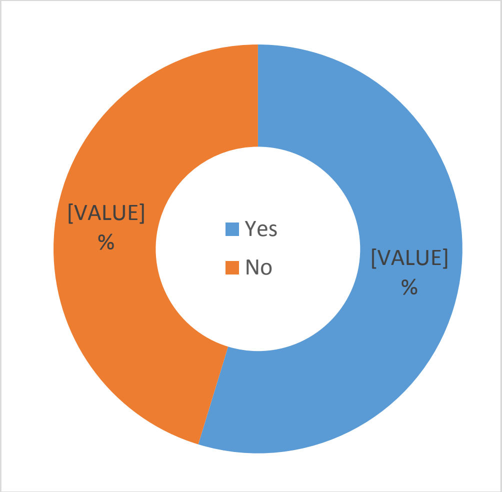

Figure 13: Chart pie comparing the percentage of respondents who have smart devices to those who do not.

It should be noted that no correlation between the comfort of the respondents with technology and the ownership of smart devices was detected within this sample. Moreover, the following graph shows that, regardless of the technological background of the respondents, the majority of them (~87%) would be interested in installing and using Smart Home technology in the future.

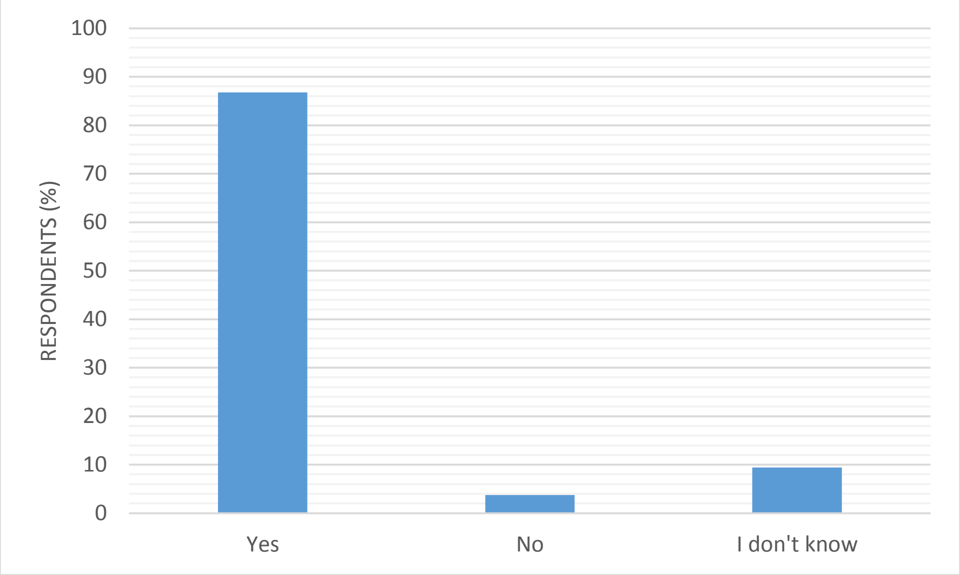

Figure 14: Graph presenting the willingness of the respondents to use Smart Home technology.

In **Question 4** of the online Questionnaire the respondents could choose among several statements regarding the usefulness and other characteristics of Smart Home technology. The statements that were chosen are the following:

“Smart Home technology is…”

• Useful and worth having	80%
• Likely to cost me more money than it saves me	26%
• Too new a technology to be reliable	19%
• Too risky –i.e. it could be hacked	19%
• Too confusing to bother with	12%

In agreement with the previous graph, 80% of the respondents believe that the use of Smart Home technology could offer them useful services. A great percentage, about 25% has worries regarding the actual savings that could be achieved by using this technology. About 20% believe that the technology may be unreliable and the same percentage believe that the technology is too risky and vulnerable to attacks. It should be noted that 50% of the respondents that consider the technology risky, consider it unreliable too. Finally, 12% of the respondents consider that the technology may be too difficult to use. Of interest is the fact that no correlation between this statement and the technological background of the respondents was detected.

In **Question 5** the participants were asked whether they would find a smart heating system that could send you notifications and suggestions useful. Only 8% of the respondents answered that such a feature would be unnecessary. The results can be seen in the following graph.

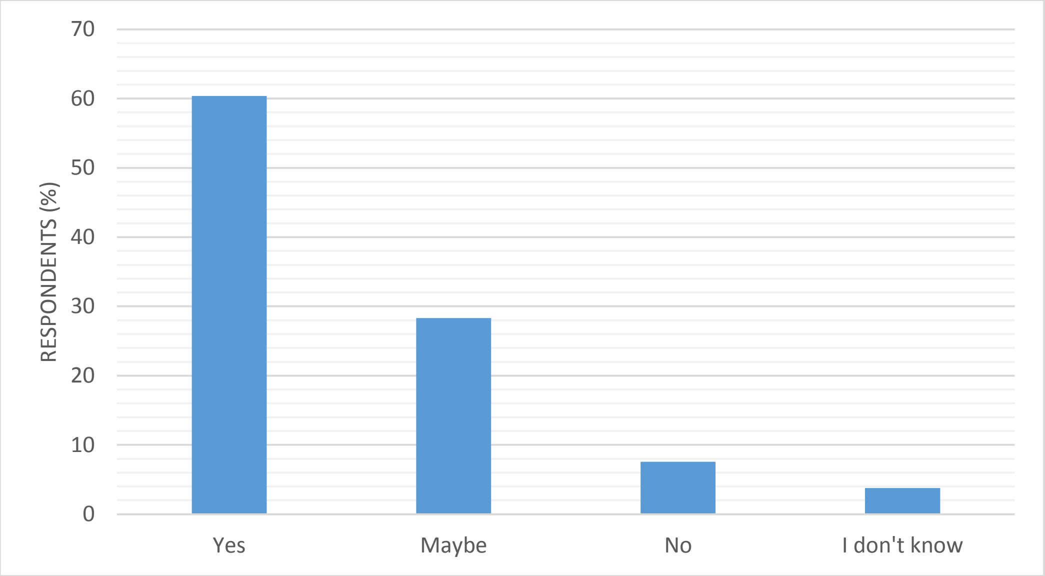

Figure 15: Respondents' interest on receiving suggestions/notifications from a smart heating system.

The next two questions, **Question 6** and **Question 7**, focused on the willingness of the respondents to share their data. In Question 6, the respondents were asked whether they would be willing to share their data, anonymously, **with other users** (e.g. via community sharing apps such as waze for traffic information) and were given the options to answer "Yes", "Yes, if my system could use their data and I could get access to other services at a reduced cost (e.g. online data storage)", "No" and "I don't know". In Question 7, the respondents answered to whether they were willing to share their data **with third-parties** for other services (e.g. future consumption forecast). The results are shown in the following clustered columns graph.

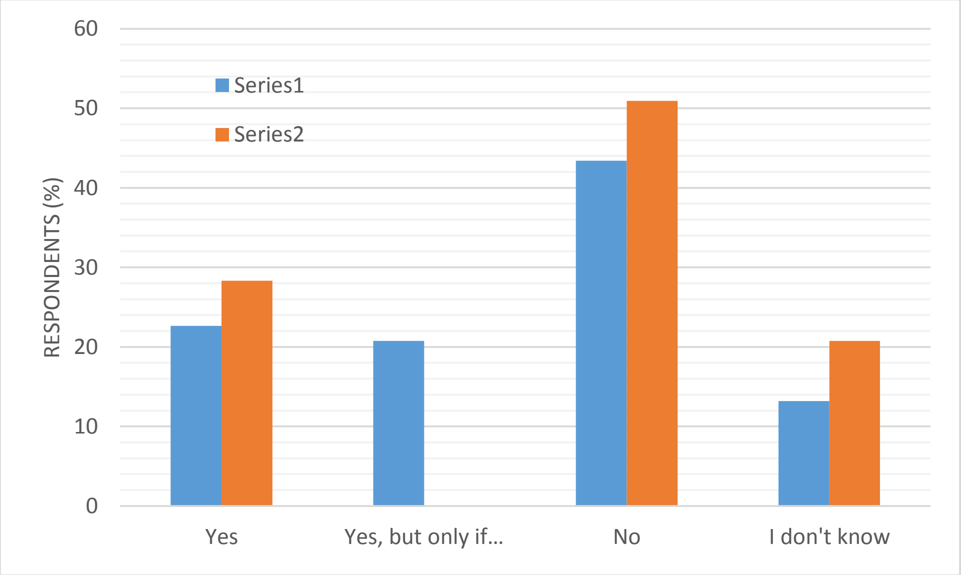

Figure 16: Willingness of respondents' to share their smart heating data with other users (Series1-Blue) and with third parties (Series2-Orange).

In both cases, more than 40% of the respondents proved to be unwilling to share their data with other entities. However, it should be noted that they were more willing to share their data with other users than with third parties, showing that a community sharing app would be more preferable than centralized services from certain companies. This is important for the components of the technical WPs that focus on the sharing and storage of users' data (like the Experience Sharing component and the COSMOS Trust & Reputation model).

In **Question 8** the participants were asked what kind of notifications or suggestions from the smart heating system they would find useful. The chosen statements were the following:

• "Temperature at X range"	89%
• "Risk of damp/condensation"	79%
• "Turn on/off the heating"	75%
• "Close window" (to save energy/cost)	45%
• Other	25%

Although the differences are slight, it can be seen that the respondents preferred notifications regarding certain parameters (e.g. temperature, humidity) rather than suggestions regarding certain actions (e.g. closing a window). However, a great percentage, 75% of them, would find suggestions regarding turning on and off the heating useful. It should be noted that, the respondents suggested some extra notifications, depending on their own needs and concerns, like:

- "Risk of frost damage"
- Estimated costs of consumption to that point.
- Weather forecast to prepare for sudden drops in temperature
- "System is malfunctioning"

In **Question 9** the respondents chose the means by which they would prefer to receive the above suggestions/notifications. They great majority of the respondents would prefer a mobile device rather than a fixed monitor at home. The results are presented in the following graph:

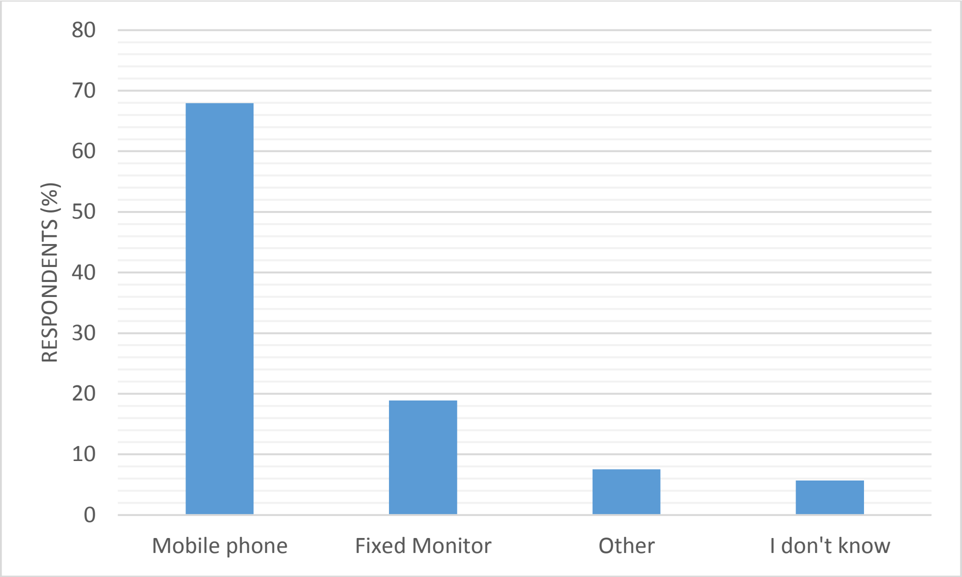

Figure 17: Respondents' preferences regarding the means of notification.

In **Question 10**, the participants were asked about the way they would prefer their home temperature to be set. Only 4% of the respondents want only the smart system to set the desired temperature (automatically) and 11% want to set the temperature only on their own through an App. However, about 66% of them would like to have both of the two previous options. Finally, 13% would prefer to set the temperature the way they do now (by using the programmer and temperature controls).

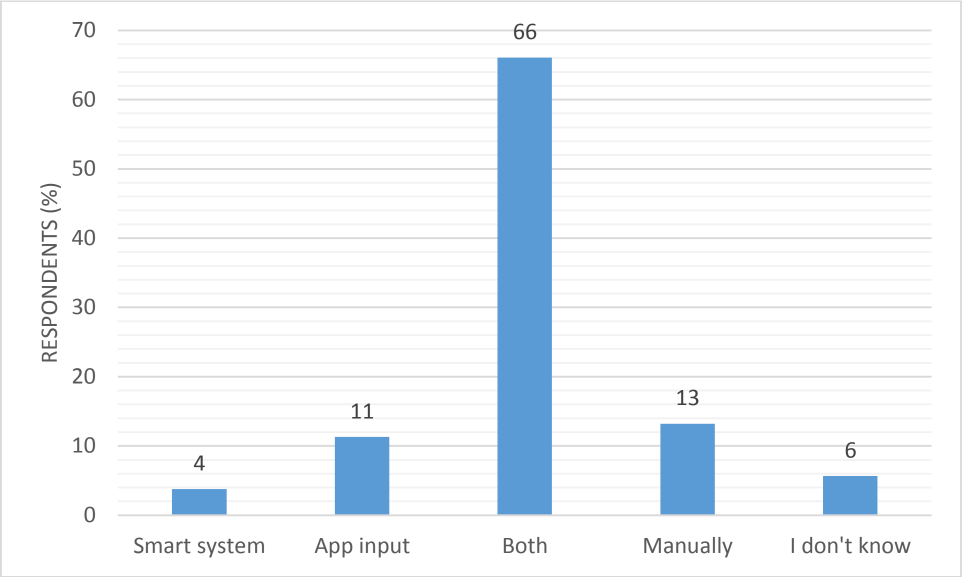

Figure 18: Respondents' preferences regarding the way of the home temperature setting.

Since the smart system could automatically turn the residents' heating on/off based on their home occupancy, **Question 11** focused on the means of home occupancy detection (without the GPS option) by using another app (e.g. Google calendar), extra sensors or manual input. In **Question 12**, the GPS option was introduced for this case, in order to provide the option of estimating when the residents will arrive home. It was proven that most of the respondents did not like the idea of automatic home occupancy detection, while the occupancy prediction from GPS readings was more accepted. The results are shown in the next two following figures.

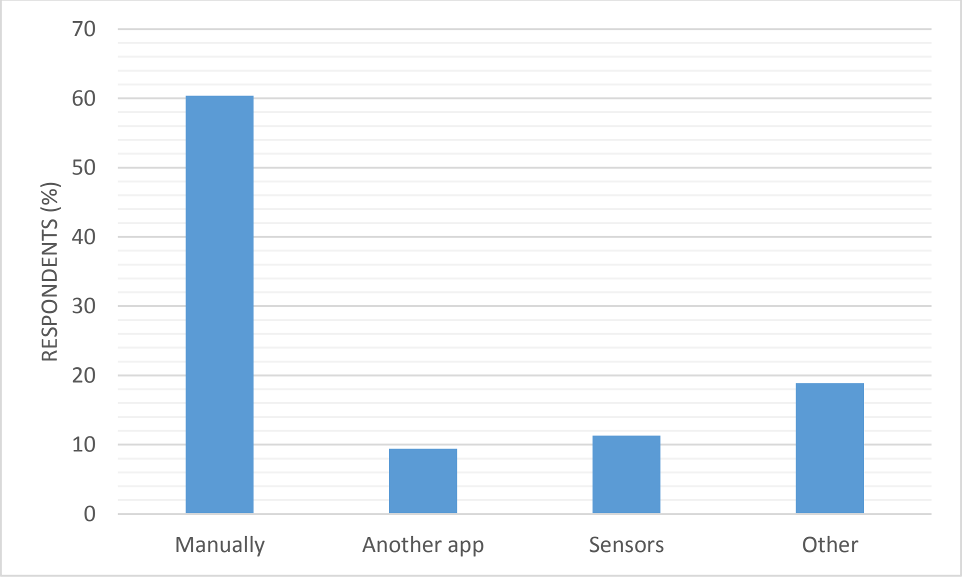

Figure 19: Respondents' preferences regarding the means of home occupancy detection.

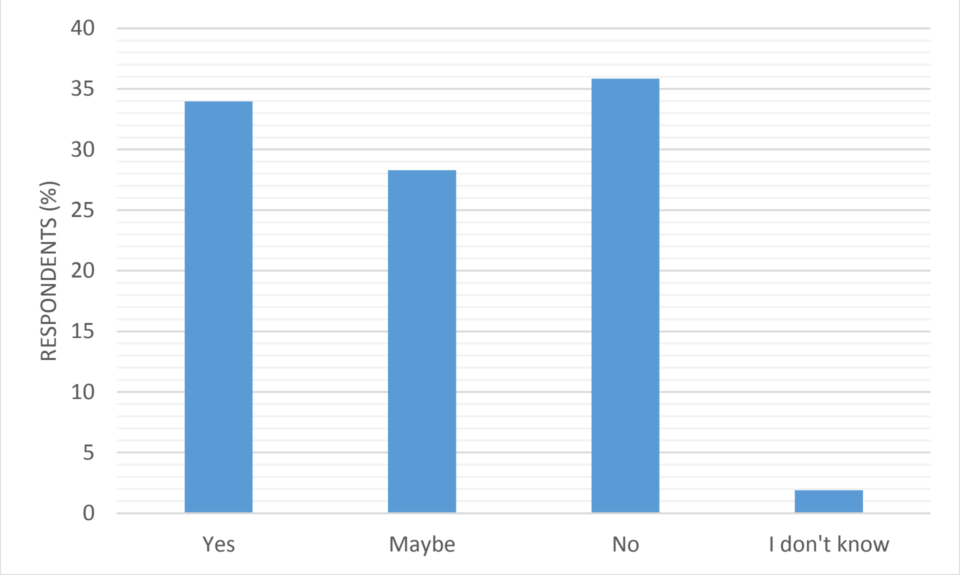

Figure 20: Respondents' preferences regarding the use of GPS for home occupancy prediction.

Question 13 focused on the interest of the respondents on providing their maximum daily or monthly heating budget as input to the system so that it could then predict if this is achievable with the current settings or send proposals to change them. More than 50% agreed with that option.

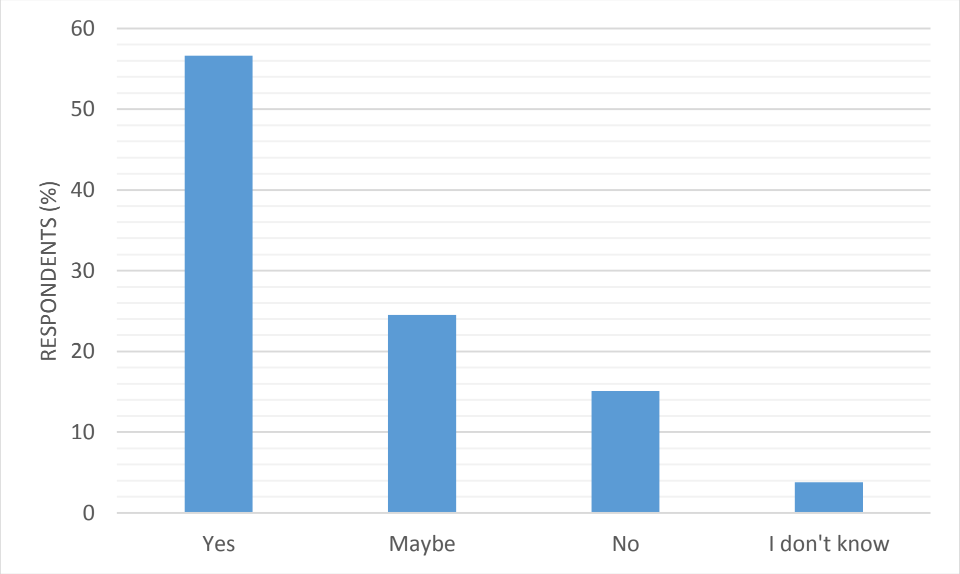

Figure 21: Respondents' interest of providing their available budget as input to the smart heating system.

Question 14 focused on the end-users willingness to provide feedback to the smart heating application. More specifically, the participants were asked whether they would you be willing to rate the performance of a smart heating system (for instance using a 5star rating interface) on a daily basis and for a few days following its installation. This would help the system to 'train' itself and learn from their specific requirements. The following graph presents the corresponding results. Most of the respondents would be willing to provide such feedback.

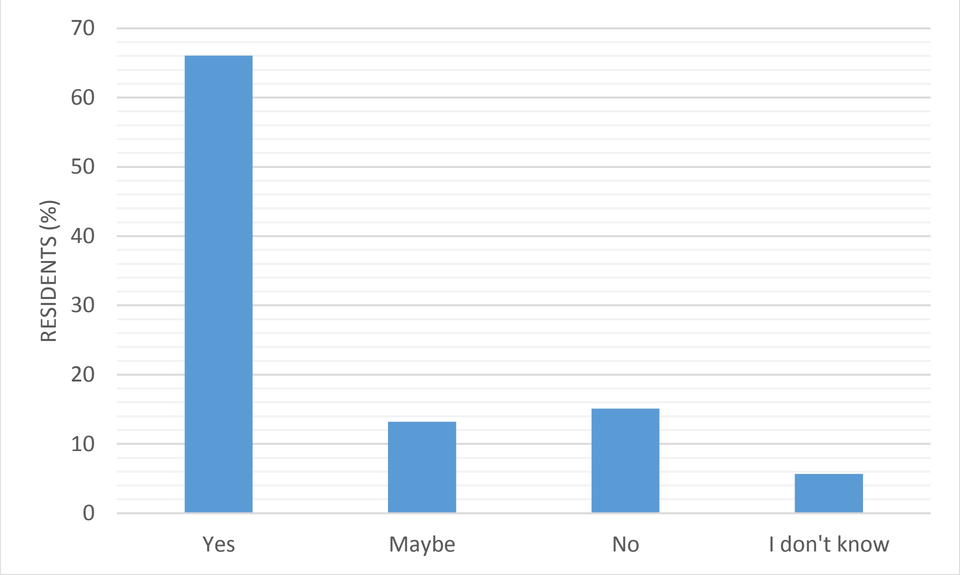

Figure 22: Respondents' willingness to rate the initial performance of the smart heating system.

In the final question, **Question 15**, the respondents were asked to think of any special circumstances in which they would need to override the smart heating system to meet their individual preferences or changing needs. The number of the responses on this question and their quality was satisfactory and it will be taken under consideration by the technical WPs working on this Use Case in order to extend the services they provide and cover more special cases. Some of the special cases for changing the heating **schedule** and **settings** that were identified are:

Period of illness and health issues	28%
Change in occupancy because of holidays, business trips, staycation, etc.	13%
Short notice/unexpected change of plans e.g. coming back from work early	13%
Additional occupancy e.g. because of visitors	10%
Individual needs e.g. elder people having different needs from younger ones	10%
Extreme weather conditions and unseasonal weather	6%
Case of repairs or system failure	6%
Doing physical work at home vs sitting down for hours	6%
Previous activities before entering house e.g. joking, swimming	2%
Cooking (needing to turn off heating or opening window just in the kitchen)	2%
Cost issues	2%

9. Scenario Progression

9.1 Damp and Condensation

Damp occurs when a fault in the building's basic structure lets in water from outside. Condensation is caused by moisture in the air. There are two main types of damp:

- **Penetrating Damp:** This occurs if water is coming in through the roof or walls, for example, under a loose roof tile, through cracks or through a faulty gutter or downpipe.
- **Rising Damp:** This appears if there is a problem with the damp proof course. There is a barrier built into floors and walls to stop moisture rising through the house from the ground. Evidence of rising damp is a 'tide mark' on the walls that shows how high it has risen and sometimes an accompanying musty smell. Rising damp will usually only rise to a height of about one meter from the ground.

9.1.1. Condensation

All houses can be affected by condensation, and it can cause mould, damage to clothes, furnishings and decoration, and leave a musty smell. Both condensation, and the problems it causes, are often mistaken for damp. Damp usually leaves a tidemark and, dependent on the cause, would need remedial treatment to the building to eliminate it.

A problem for landlords is being able to differentiate between the two, as it would be up to the landlord to resolve damp issues caused by disrepair to the building, but it should be the residents' responsibility to address condensation issues, as these can be remedied by changes in lifestyle. However, left untreated, condensation will cause mould growth, and excess moisture within a dwelling will cause long-term disrepair. Therefore, traditionally, social landlords, such as Camden Council, are called on by residents to address the issue.

Condensation occurs when moisture in the air gets cooler and tiny droplets appear on surfaces. Generally, it is more likely to occur during cold weather, as surfaces are colder and more space heating is required. It also occurs when a home is poorly ventilated and there is little air movement, e.g. behind furniture (especially when positioned against external walls), in room corners or near windows. If left untreated, mould will grow.

9.1.2. Camden Case Study

Condensation accounts for approximately 70% of damp problems reported by Council residents. The lack of balance between heating and ventilation in dwellings is a major contributor, and residents generally report it once mould appears on walls and furniture. It increases dust mite population, which may in turn lead to an increase in health problems.

Figure 23: Dust mites thrive in environments with high relative humidity, and their faeces are a human allergen, causing respiratory problems.

Similar to other forms of dampness, condensation also makes houses more difficult to keep warm because wet building materials lose heat more quickly than dry ones, and some of the heat input is being used to dry out the house[1]. Condensation is detrimental to both physical and mental health.

Camden Council receives a significant level of calls reporting cases of condensation. These come through the Wish Plus referral service, via the Green Camden Helpline or directly through the Camden Repairs Service contact centre, which receives the majority of complaints.

500 council residents reported issues with damp and/or condensation between October 2013 and August 2015 to the Repairs service. They receive a visit from a Customer Service Officer (CSO) who assesses if the issue is condensation or damp, and if any repairs are needed. The resident is sent a condensation information leaflet, and is advised that a follow-up call will be made after 4 weeks. Any required repairs are reported to the relevant section within the department.

A Case Management Officer (CMO) tracks each case and does the follow-up call to the resident to ensure the advice has been followed, and to assist if the issue has not been resolved. The aim is to work closely with the resident by empowering them to take action and agree to certain commitments, e.g. cleaning mould off walls, ventilating the flat whilst cooking or moving furniture away from cold walls. These commitments are then followed up and recorded to ensure that action has been taken. Residents are provided with a start-kit comprising of a moisture absorber, anti-fungicidal wash, hygrometer and condensation wall chart. In some cases, a survey is required to determine if the problem is condensation; this is performed by a Contract Manager (CM), who will make arrangements to remove mould and provide advice. In severe condensation cases, additional repairs and improvements are arranged, for instance, upgrading extractor fans or providing new home ventilation systems. A further follow-up visit is arranged to check progress.

This process has proved to be effective, but labour-intensive and costly to the council. The following table shows the average resource cost for each case raised:

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[1] (Energy in the home (NEA Campaigning for warm homes) ISBN 0 948371 25 0 Section 7 Pg 6).

Table 4: Human resource costs in damp detection and remediation

Resource	Average time per case raised	Cost (£)
CSO	1h	30
CMO	2h	60
CM	6h	300
	TOTAL	**390**

The following case study shows a two-bedroom ground-floor flat, where every room was affected by condensation. As can be seen in Figure 24, there is a high level of clutter in the property, and a lack of ventilation and airflow.

Figure 24: Case Study – before intervention. Ground floor two-bed flat with three adults and two children.

Following extensive visits, advice and interventions from council officers, all the mould was removed and all indications of condensation were eliminated (see Figure 25). Humidity and moisture levels had been reduced, and the tenants had received training and information on how to manage condensation.

Figure 25: Case Study – after intervention. Ground floor two-bed flat with three adults and two children.

9.1.3. COSMOS

The issue for Camden, and for other landlords, is the resource-intense nature of addressing condensation issues.

COSMOS can help as, by using data from humidity and temperature sensors, alongside data from heat meters, Camden can remotely monitor and assess behavioural patterns which could lead to a risk of condensation. The COSMOS platform would enable predictions regarding the dew point (the point at which condensation is triggered) in relation to humidity, ventilation and temperature.

The information gathered would allow personalised advice to be produced, which could be sent to residents through their heat meter tablet, smart phone, via email, etc. A follow-up process can be established to regularly and remotely monitor each case and continue providing support to the resident until the proposed measures have been implemented and the risk of condensation reduced. Not only does this save the expense of visits by the council, but it is far more convenient to the resident, as allowing access for council officers is not required.

The system can also issue alerts to the appropriate council departments for further resident support which, in some cases, could stop residents going into fuel poverty, and can also be developed to be individual without the need for resource-intensive visits to the resident's home.

Camden has identified two severe cases of condensation from recent "Well and Warm" fuel poverty service that could be used to pilot the COSMOS system. The table below summarises the main issues in each property:

Table 5: Family and resident types used for the study

Property A	**Property B**
Mould throughout the property.	Bad case of mould in bedrooms and hallway – soggy to touch. Heating system not working properly.
	Family with children. One person with severe health problems and respiratory difficulties.

Residents have already been contacted and sensors have been installed. Both households confirmed that the problem still exists, and both welcomed the idea of a remote monitoring system.

Piloting the platform on these two properties will enable the COSMOS consortium to quantify the overall benefit of using COSMOS controls against the benchmark of the traditional solution, as outlined previously.

10. Recommendations

10.1 Overall Recommendations

In this section, we will highlight the courses of action that we wish to take in commercialising COSMOS, based on our findings in Chapter 5. We aim to objectively suggest areas of COSMOS that require further focus, recommending particular topics to research, concepts to develop further and techniques to continue improving upon.

10.1.1. Privelets and Node-RED

To achieve end-to-end security over all COSMOS components, we utilise the Privelets technology and implement Node-RED as a linking component. We must ensure that all standard protocols are followed to ensure that the encryption is secure and that these technologies are not so heavy that it will cause latency in the system.

10.1.2. Planner and Experience Sharing

Another important recommendation is to find the best way of allowing the VEs to communicate their experiences, and not just their raw data or state space. We must find the balance between the speed of having logic done locally, and the efficiency of having logic done in the highest level of COSMOS. This is particularly crucial for the implementation of Case Base Reasoning and Experience Sharing. It is also recommended that we constantly look to extend the Case Base, so that it can deal with a multitude of different scenarios. The usefulness of this technology heavily depends on the size and diversity of the Case Base, and therefore we must aim to constantly extend and refine it.

We should also aim to understand the archetypical cases that may apply for a wide range of applications, for instance, VEs that have mobility or VEs that describe environmental conditions, and how they may link to generalised actuation plans, i.e. change heating, lighting or humidification.

10.1.3. Machine Learning

In terms of analytics, we should use the comparisons of different Machine Learning techniques for classification done in D2.2.3 and regression for archetypical Use Case Scenarios such that general re-use is possible. Researching many possible ways of modelling our system so that End Users can interact with these complex technologies is of paramount importance to COSMOS, as we need these models to make sense to human observers and application developers. There is also great benefit in getting the system to adapt dynamically and improve over time in an unsupervised way.

We should aim to run quality control and bug testing thoroughly on the CEP-based technologies, as this technology may have limitations in large deployments, especially if rule sets are authored by multiple parties.

Furthermore, we should follow a 'trial and improvement' approach when developing the Experience Sharing API, to understand if the best experiences are winning and ensure that there are no conflicts in experience ratings causing poor results.

10.1.4. Practice System Issues

Finally, it is recommended that we research how to make the communication in the Heating

Network as reliable and efficient as possible. Issues such as a volatile Internet connection can cause problems, such as missing data values and infrequent data transfers. So far, this issue seems to have been either accepted or overlooked, but it is important to find ways of ensuring that the data is regular and complete as the entire COSMOS platform relies on it.

11. Conclusion

It has been possible to assess technology that is new and improved in Year 3. Most of the evaluation has been done on either prototypical systems or mostly implemented technologies.

We had the chance to get direct feedback from residents that were interacting with the technology produced within COSMOS and augment the Playbook and User Interface guidelines to reflect the in situ findings from the Use Cases that were implemented.

There is still much work within the wider research community that will be required to balance the technical requirements with emerging usability and trust concerns from end users.

Our evaluation is optimistic for commercial opportunities in key areas where innovation is occurring, namely the CBR Planner, Privelets and UrbisAPI. We have observed that:

- Using a decentralised approach allows COSMOS to benefit in terms of efficiency. CBR is making a big impact such that low-resource devices can become intelligent, Case Bases can be exchanged for Experience Sharing and generalisation for CBR can be widely applied.
- Privelets allow us to authenticate communication between devices, whilst the use of Node-RED allows us to streamline these processes and link many components together in an intuitive way.
- Our Next Steps for the UrbisAPI platform will be to add additional key functionalities of User Interface components, so that it is ready to be sold to cities for IoT. In addition, the hardware will be industrialised so that it is durable and compatible with any market and industry, facilitating the sales of UrbisAPI to as many cities as possible.

Design to deployment process was tested in the application of the humidity and damp scenario in that within a reasonably short amount of time, a sensor was able to be designed, produced and deployed within the COSMOS architecture to enable an application. This shows the flexibility and cost effectiveness of IOT when the reference architecture is employed.

City systems are expressing a clear interest in adopting IoT, so working systems that are able to realise business processes be sure to have a large impact. The next steps for UrbisAPI is to continue to run services for cities and show impact within Camden as a legacy to COSMOS.

12. Appendix A

12.1 Participant Profile Questionnaire

Ref _______

Ethnicity: What is your ethnic group? (Please tick one box)		
White	English/Welsh/Scottish/Northern Irish/British	
	Irish	
	Gypsy or Irish Traveller	
	Any other White background (please specify)	
Asian or Asian British	Indian	
	Pakistani	
	Bangladeshi	
	Chinese	
	Any other Asian background (please specify)	
Black or Black British	Caribbean	
	African	
	Any other Black/African/Caribbean background (please specify)	
Mixed/multiple ethnic groups	White and Black Caribbean	
	White and Black African	
	White and Asian	
	Any other mixed/multiple ethnic background (please specify)	

Other ethnic group	Arab	
	Any other ethnic group (please specify)	

Age: What is your age? (Please tick one box)									
0-15		16-24		25-34		35-44		45-54	
55-64		65-74		75-84		85+			

Gender: What is your gender? (Please circle the answer)			
Male	Yes/No	Is your gender identity different to the sex you were assumed to be at birth?	Yes/No
Female	Yes/No		

Highest level of education gained: (Please tick one box)				
School		University		Other (please specify)
College		None		

Family status: (Please tick one box)			
Live alone		Live with children	
Live with partner		Live with partner and children	
Live with extended family (please specify)			

END OF THE QUESTIONNAIRE

12.2 Home Heating Questionnaire

Ref _______

1. **How comfortable do you feel using technology? (Please tick one answer)**

Not at all		Comfortable		Very comfortable		Don't know	

2. **Please rate (1-5) how important each statement is to you when heating your home.**

(1 – Extremely important, 2 – Important, 3 – Don't know, 4 – Not important, 5 – Extremely unimportant)

I want to keep my heating within my budget.	
I want to keep my home warm and comfortable.	
I want to control my heating from a mobile/computer.	
I don't want to interact with my heating controls (I prefer fully automated controls).	
I want to keep my home healthy.	
I want my heating system to operate correctly.	

3. **When you are cold in your home, what do you do first? (Please tick one answer)**

I wear more layers.		I turn the heating on or up.	
I use additional heaters (e.g. electric heaters).		Other (please specify)	

4. **Would you like to have a smarter heating system in your house? For example, a system that can manage the heating on its own after learning your heating preferences. (Please circle one answer)**

Yes / No / Don't know

5. **Would you like to have a remote control for your heating system? For example, so you can warm your home before arriving using a mobile phone, etc. (Please circle one answer)**

Yes / No / Don't know

6. **Would you like to have a remote control for your heating system? For example, so you can warm your home before arriving using a mobile phone, etc. (Please circle one answer)**

Yes / No / Don’t know

7. **Would you like to the temperature of your home to be automatically adjusted according to outside weather conditions? (Please circle one answer)**

Yes / No / Don’t know

8. **Please rank (1-3) the following statements in terms of what is most important to you, with 1 being the most important.**

Having a smarter heating system that learns from my heating preference.	
Having a remote control for my heating system.	
Having the temperature of my home automatically adjusted according to weather conditions.	

9. **What information do you find most useful on your heat meter? (Please circle one answer)**

Instantaneous energy consumption	Historical energy consumption	Weather	None

10. **What additional information would you like to see on your heat meter? (Please specify if ‘none’ or ‘don’t know’)**

11. **Do you think that your heat meter helps you to save energy? (Please circle one answer)**

Yes / No / Don’t know

If you answered ‘yes’ or ‘no’, please explain why.

12. What is your ideal heating control? For example, fully automated, manual only, etc.

END OF THE QUESTIONNAIRE

13. Appendix B

Risk Assessment Table

No	**Key Objective / Identified Risk(s)** [Threat/Opportunity]	**Current Controls**	**Assessment of Risk Score**			**Action Plan to Improve Control** and/or additional control measures	**Assessment of Residual Risk**			**Responsible Officer**	**Timescale/ Review Frequency**
			As it is now with current controls				With control measures implemented				
			Likelihood (Probability) *[L]*	**Impact** (Severity) *[I]*	**Risk factor** *[IxL]*		**Likelihood** (Probability) *[L]*	**Impact** (Severity) *[I]*	**Residual Risk Factor**		
1	Resident gets no heating when windows are open	Residents can shut the window for the heating to be re-established	5	4	**20**	No sensors to be placed in kitchens and bathrooms as residents are more likely to have these windows open.	1	3	**3**	Hildebrand	weekly
2	One or more sensors fail and turns off the heating	Resident to contact repairs call centre	3	5	**15**	Direct help line to be set up. This will reduce response time to resolve faults. Sensors to be tested prior to installation and during commissioning.	1	3	**3**	Hildebrand Camden	on installation and then daily
3	Air draughts from faulty windows turn off heating	check with residents if any issues of draughts	3	5	**15**	Draft proofing or similar measure to be provided to reduce draughts. Air tests prior to installation to determine extend of issue	1	5	**5**	Camden	on installation
4	Residents remove sensors	Pre-selection of volunteers excludes families with children, as these are more likely to pull the sensors. Briefing residents on project objectives and interaction with sensors	2	5	**10**	Recording occurences when sensors removed so data is not affected. Checking with residents for reasons why sensors removed	1	1	**1**	Camden	weekly
5	insufficient number of volunteers for sensors	compensation to volunteers in the form of gift vouchers	2	5	**10**	Create a reserve list of back up volunteers	1	5	**5**	Camden	one off
6	insufficient attendance at survey /workshops	Invitation letters and posters publicising the workshops to large number of residents	5	5	**25**	Incentives in form of vouchers and refreshments for participating	2	5	**10**	Camden	one off