Project Net Zero Terrace SIF Alpha

Subject SLES System Architecture and Use Cases

Deliverable M2 D2 System Architecture Report

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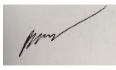
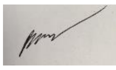
Revision	Description	Issued by	Date	Approved (signature)
1	Description of system architecture and use case approach	SG	25.3.24	
2	Addition of glossary, further standards, KPIs and introductory/conclusive remarks	FF	23.5.24	

GLOSSARY

Actor	An actor is a device, person or anything else that interacts with the [SLES] system and its components
API	Application Programming Interface – an intermediary that allows communication between two software components. They are often used to allow a client to view/input information on a database without having to directly enter the database itself.
CEE	Centre for Energy Equality
CEMS	Community Energy Management System
COTS	Commercial Off-The-Shelf
CRM	Customer Relationship Management
DNO	Distribution Network Operator
Domains	There are 5 domains that make up the electrical energy conversion chain on the Smart Grid Plane. These are: Bulk Generation, Transmission, Distribution, DER (Distributed Energy Resources) and Customers Premises
DSO	Distribution System Operator
FEMS	Feeder Energy Management System
Flexibility (modes)	The four modes of flexibility that the NZT scheme aims to achieve are: 1) Optimisation of demand and generation to reduce bills 2) Optimisation of demand generation to reduce peak export (voltage management) 3) Optimisation of demand and generation to reduce demand on networks (thermal management) 4) Optimisation of demand and generation for national balancing
HEMS	Home Energy Management System
Historian	A data storage system used to capture, store and manage large quantities of time-series data.
IEC	International Electrotechnical Commission
IoT	Internet of Things
NZT	Net Zero Terrace
PAS	Publicly Available Specification
SGAM	Smart Grid Architecture Model
SIF	Strategic Innovation Fund
SLES	Smart Local Energy System
TSO	Transmission System Operator
VM	Virtual Microgrid
Zones	There are 6 zones that make up the hierarchical levels of power system management on the Smart Grid Plane. These are: Process, Field, Station, Operation, Enterprise and Market

1 Introduction

This document outlines the approach and current progress including recommended next steps in developing the systems architecture for the Net Zero Terrace SIF Alpha project. The Net Zero Terrace concept includes for a smart local energy system (SLES) which is aimed at enhancing benefits to consumers/network customers by delivering the following:

1. The reduction of consumer bills by optimising consumer energy consumption to meet network demand
2. The enabling of local energy models and services including maximising use of community energy assets and the fair share of local energy across the community.
3. The provision of new energy services to consumers including integration with a consumer app "Fairer Warmth"
4. The delivery of flexible services where flexibility is defined over 4 modes of operation:
    a. Reducing customer bills by optimising demand with energy generation
    b. Reducing voltage impact on DNO networks
    c. Reducing thermal load on DNO networks
    d. Balancing generation and demand in support of national balancing services.
5. Demand and generation whilst also delivering financial value to consumers.
6. Reducing the overall cost of deployment of the ambient loop, low-carbon heating solution to homes
7. Providing a source of data, information and analytics to continue to improve people's lives through further development of the NZT scheme.

2 Key Performance Indicators

There are several KPIs that can be potentially applied to the SLES once it is in use. These include:

- Comfort level of consumers – Measurement of both physical outputs (e.g. time spent at optimum house temperature) and psychological outputs (e.g. consumer contentment)
- Affordability for consumers – Measured primarily by comparison of energy bills
- Success of the scheme achieving flexibility – Measured by various means to assess whether the system achieves the four modes of flexibility (see glossary and *M3 D3 Energy Model*)
- Out of Tolerance – Measure through system deviation from expected performance profiling. This could potentially be achieved by usage of the HEMS system (see *section 3.2*)
- Satisfaction of DNO – Measure by both quantifiable metrics and interaction/questionnaires
- Community energy consumption – Measurement of consumption and then comparison to the anticipated amount. The NZT scheme aims to achieve payback on community energy system, so a certain amount of community energy must be used in order to deliver value.

It must be noted that these are examples of potential KPIs, but this list may be expanded (or reduced) once the system is developed further and implemented.

3 Design Approach

The following sections summarise the design approach taken to develop the SLES under SIF Alpha:

3.1 Architecture and use case design

The system architecture model aims to outline the various components within the Net Zero Terrace Scheme, and not only show system schematics showing how they work together, but also demonstrate the purpose of each component and it feeds into the ideal function of the system.

To optimise the system architecture model, 'use case design' has been employed. Use case design is a method of analysis to identify system requirements.
A key concept in use case design is an actor. Actors can be defined as anything that interacts with the system (i.e. the SLES) and its components. These are typically devices or people. Some of these people can be considered stakeholders in the system, and interaction with them helps to develop "use cases" – specific ways in which the actors interact with the system. Analysis of these allows for better design of the SLES.

To inform the initial design approach when developing the SLES, The Cenelec Smart Grid Architecture Model (SGAM) is used [1]. Shown in **Error! Reference source not found.**Figure 3-1 is the SGAM Plane, which summarises the model

[1] Cenelec Smart Grid Reference Architecture (cencenelec.eu)

diagrammatically. The current process focuses on identifying high level components in the component level and then determining the functional layer required to deliver against the SLES business requirements outlined above. The business layer is to be further developed as the service model is developed, but the current desired outcomes are those described in the introduction above.

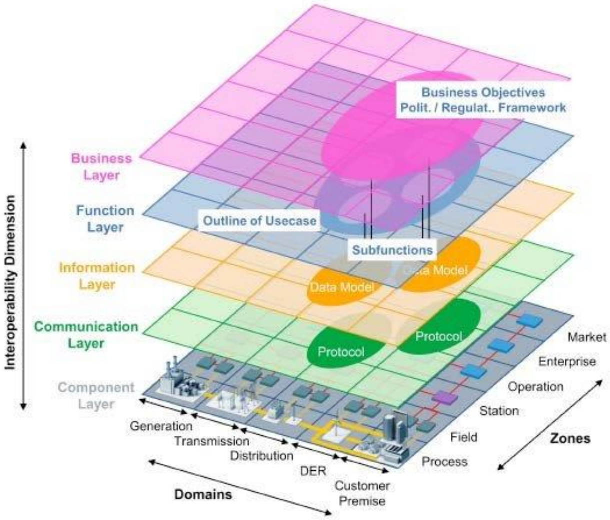


Figure 3-1 SGAM Smart Grid Plane

The architecture is then further developed from an initial concept architecture to a "Level 1" architecture that describes the individual actors and identifies their interactions with other actors in the system.

High level use cases are then developed for each actor. These describe the purpose of the actor and its interdependencies.

The design process is iterative as more understanding of the interdependencies of different actors is explored. Figure 3-2 below describes this iterative process whereby regular reviews are undertaken as the design evolves.

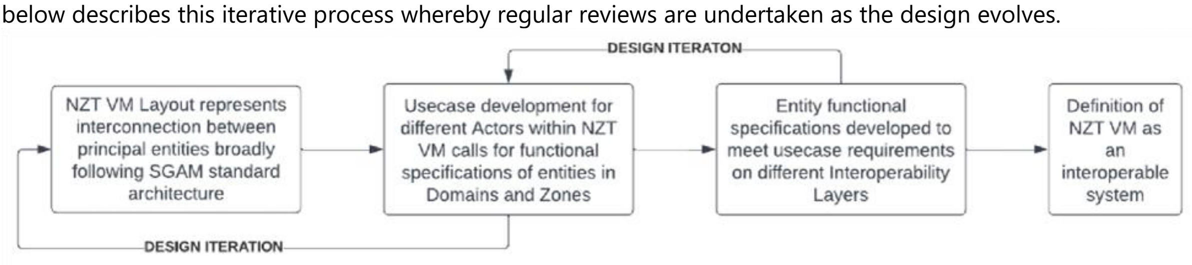


Figure 3-2 Iterative design process

3.2 Concept architecture

Using the concepts outlined above, a concept (or 'level 0') architecture model was created. This also drew from the NZT Discovery Stage, where a concept of a digital representation of key parts of the system was explored. This used the concept of management systems to represent the various parts of a potential system – the home (HEMS), community (CEMS), DNO (DNO interface), consumer (Fairer Warmth app) and energy supplier. In this stage, functions for each of these systems have been developed in more depth. Additionally, tools which be used to deliver the NZT scheme have been included, such as a Digital Twin, the Fairer Warmth app, and smart metering.

Figure 3-1 (overleaf) describes the initial concept architecture that was developed to understand the core components, their interactions, and their subfunctions:

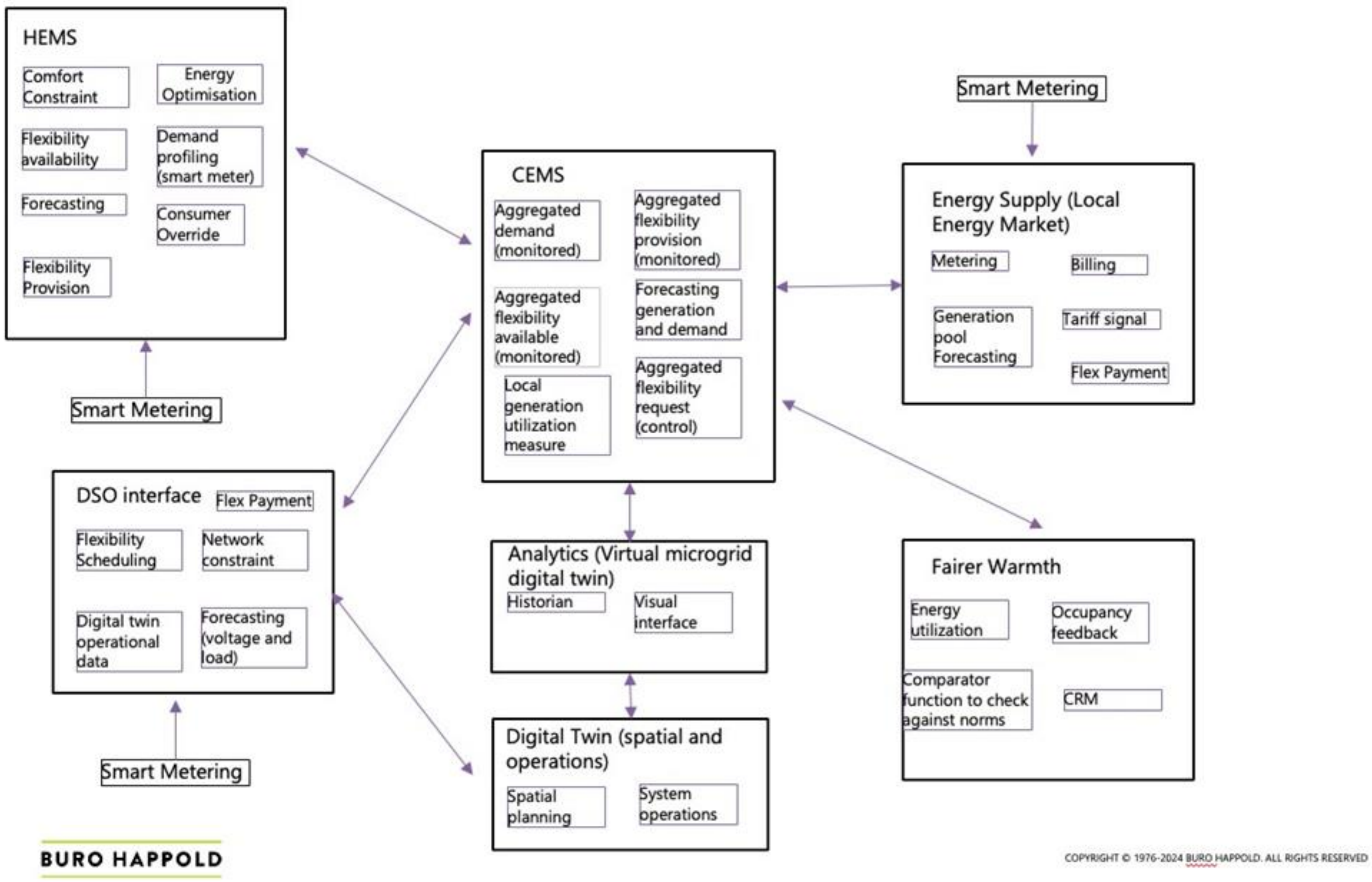


Figure 3-3 – Concept architecture

The core components shown in Figure 3-3 are described further below:

3.2.1 Home Energy Management System (HEMS)

The HEMS is a system that represents an individual home within the digital 'ecosystem'. The HEMS is responsible for ensuring comfort for occupants, understanding what flexibility can be provided from the in-home energy system to the wider ecosystem, and how to optimise energy consumption in the homes to reduce the bill. The HEMS ensures the bill remains low once houses have already been decarbonised through both the supply of increasingly low-carbon electricity and the removal of gas-supplied equipment. It needs to have the ability to externally communicate with a community energy management system (CEMS), a smart meter, and IoT communications to in-home devices for controlling and managing the energy demand.

In-home devices may include:

- Hot water control
- Space heating control
- Energy storage systems i.e. batteries or hot water store

The HEMS may access smart metering data to deliver its services, understand energy consumption and demands, and obtain information on current spend and budgets.
It could also have access (directly or indirectly) to the external community app –"Fairer Warmth" if deemed applicable to support the delivering of consumer services.

3.2.2 Community Energy Management System (CEMS)

The CEMS is a system that represents the community within the digital ecosystem. The community we have considered is a cluster of homes on the same ambient loop (alongside any local generation that may sit locally but not on the homes), but in practice from the perspective of aggregation in the CEMS the community is not restricted to any particular size and could be expanded to include a greater number of homes at regional scale (depending on the need). It should be thought of as a service mechanism that enables the aggregation of multiple homes (via the HEMS) to be managed. This management is in the form of a wider network that can deliver multiple benefits of scale. It has multiple functions:

- Aggregate demand of clusters, and understand/predict the demand profiles across multiple homes forming a cluster
- Aggregate community energy e.g. local roof top in the form of generation profiles and evaluate/optimise this against the demand profile
- Determine and aggregate flexibility across the community, as well as predicting and delivering flexibility provision to the DNO network and national balancing services.
- Forecast generation and tariff adjustment, communicating this to the HEMS to inform on demand profiling
- Instruct HEMS to deliver flexible services
- Integrate with any community assets e.g. community batteries requiring control
- Integrate into a digital twin and analytics process
- Feed data into a historian (data storage system, see glossary) for optimisation of energy services
- Integrate into the DNO/DSO active network management system at a higher level than feeder level, taking instruction and providing response as required within agreed constraints
- Provide a community interface to the Fairer Warmth app for insights, learning and community response.

In addition, if required it can be used to communicate community tariffs as price signals to the HEMS which may be done separately from the Energy Supplier as a virtual behind the meter system.

3.2.3 DSO interface

The DSO interface represents the DNO network and its interaction and forms another component of the SLES concept architecture.

This will be primarily used in the event information, and control functionality is needed to deliver flexibility services onto the network. For example, communicating directly with active network management services. However, this functionality could also be via a flexibility market platform or through time-of-use signals (akin to a time-of-use tariff). The architecture provides the provision for receiving instruction from the DSO and providing monitoring and feedback to the DSO on flexibility provision or response. It should be compliant with the DSO standards for data and information exchange.

3.2.4 Energy Supply

The energy supply interface is another component of the SLES concept architecture, and represents the interface to the energy supplier, which provides the energy tariffs and billing services. This can be delivered and managed by any licensed supplier with the ability to access smart metering data. The preference is for an energy supplier function that can also retail the community energy and provide billing services for that supply which will be based on the agreed metering infrastructure and function.

The metering infrastructure will allow submetering of community energy to support the 'fair share' model whereby irrespective of a household consumption the metered local solar may be distributed via the whole community to cater for its contribution to overall community demand. This relies on a supplier function that understands and meters overall community consumption and demand and then proportionally allocates onsite or other community renewables to reduce bills which may be as a tariff reduction or a rebate.

The architecture has provision for multiple tariffs based on time of use which may include from different generation mechanism (e.g. wholesale vs local energy). This may be interpreted as a single agile tariff structure or multiple tariffs derived from different generation sources.

3.2.5 Consumer/community App (Fairer Warmth)

The use of an app for consumer/community engagement and service delivery is considered a key benefit in both obtaining and providing digital information to consumers, to the service delivering entity and into the system for the purpose of analytics and profiling. The Centre for Energy Equality (CEE) Fairer Warmth app will be used to develop and test the architecture. There are two versions of the app, one for direct consumer use and one for the provision of community services. For the initial concept architecture the differences are not distinguished as it is treated as a single service model.

As the consumer is represented digitally it permits different and enhanced opportunities for interaction and learning across multiple households as well as tailored offerings per household that would not be otherwise possible via just the HEMS or smart metering interfaces.

The core functions expected from the app are:

- Customer Relationship Management (CRM) – all sensitive personal information that is used for digital service provision outside of the billing management system used by the Energy Supply function shall be retailed within the Community App function
- Consumer feedback – feedback on service options and performance for learning and refining the model may be collected via the app
- System feedback options that are felt relevant to service provision will be fed to the community app for intervention – this can include for example digital information that raises concerns on energy consumption, incorrect use of the heating system, or health monitoring concerns from the household.

3.2.6 Digital Twin

A digital twin is a tool which digitally represents the physical infrastructure of households, community (including profiles for consumers) and the network (through inclusion of the digital twin of the Electricity North West network). In this way, it could be said to act as a digital representation of the SLES as a whole. It should be noted that this digital twin is different to the spatial planning digital twin (see *M5 W7 System Planning Approach*), which is used for optimal implementation of the NZT scheme, rather than its functional operation.

The digital twin will be used to visualise and understand current and historic system performance with digital representation of all the components/actors described above. The digital twin can also represent the DNO network assets as well as behind the meter assets to better determine system response and the corresponding network impact.

A key part of the digital twin is that it allows interaction with the system in an intuitive way. This will most likely be through use of an API. However since it is still to be designed, this may not necessarily be the method of interaction.

3.2.7 Analytics

As well as data transfer between actors for operational and monitoring purposes, the use of a historian will allow archiving and review of data to permit analysis of system performance and behaviour. This is considered vital in refining the service model and its associated digital system. This is not only for benefit of the current system and but also for improvement in future system operations.

4 Further developing the architecture

Following the design of an initial concept architecture, which focuses on core functionality, the SLES architecture was developed further to include wider functionality that may be required for the NZT implementation. Figure 4-1 exemplifies how the concept architecture was expanded using the design process.

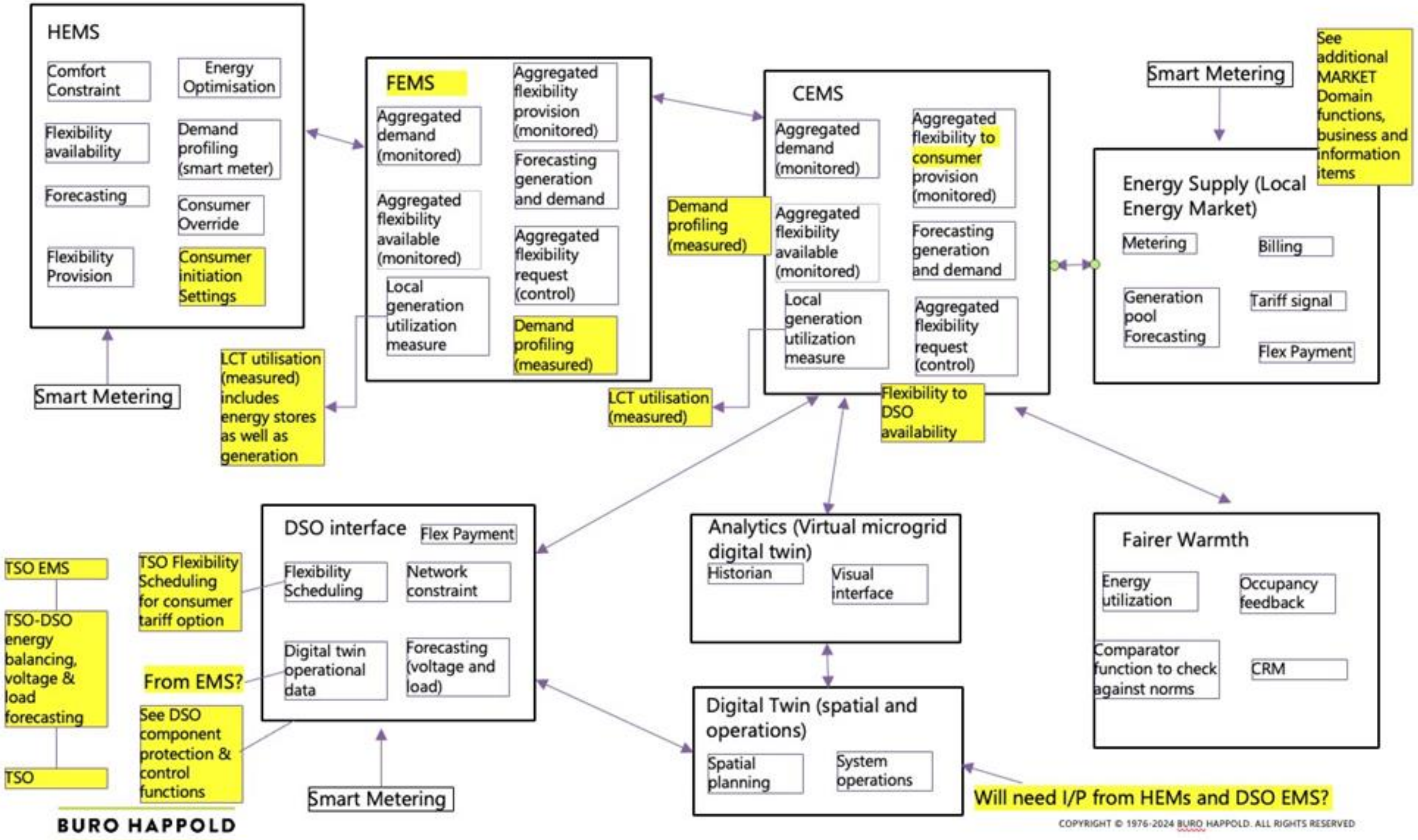


Figure 4-1 Iteration of the concept system architecture

Two key functionalities added in this expansion were:

- An additional component/function block, the Feeder Energy Management System (FEMS)
- An interaction to the Transmission System Operator (TSO).

Their functionalities are described further below:

4.1.1 Feeder Energy Management System (FEMS)

The FEMS can be considered either as a sub function of the CEMS, or as an individual function in itself. This is to be confirmed in later iterations of the architecture.

Its purpose is to distinguish between control and management at the different cluster and DNO electrical levels, effectively representing the streets of homes on an electrical feeder. This can be used to monitor feeder performance, predict impact and effects at feeder level, and use local distribution system and smart metering data to determine any response needed at feeder level. It may also interact directly with community assets at feeder level e.g. a community battery system or a community inverter managing and able to curtail the solar array on rows of terraces.

4.1.2 TSO interface

The TSO interface represents the ability for the architecture to cater for national balancing services. National balancing provision has been tested with individual consumers via energy suppliers and there are current developments underway to permit lower tier involvement from the networks directly in national balancing mechanisms. The architecture via the aggregating function of the CEMS will be able to forecast and respond to flexibility mechanism requirements for national balancing. This may for example be in reducing or increasing demand by utilising behind the meter storage systems, community storage assets or adjusting user profiles within the HEMS.

4.2 Level 1 architecture

Appendix 1 shows the next level down of the architecture, with different actors and interfaces described. This is structured also to align with the SGAM hierarchy.

4.3 High level use cases

For each of the actors described in the Level 1 architecture a set of use cases are described, identifying the high level functionality and interfaces to that actor and relates use cases.

5 Next Steps

The following next steps are outlined to continue development of the system architecture:

5.1 Learnings from HEMS testing

Under Alpha funding soft market testing of a selection of HEMS systems has been carried out. This involved developing and issuing a test functionality matrix approach to evaluate their offerings against the anticipated requirements. This included understanding current functionality and any functionality that is also in development by the HEMS providers. The overall purpose was to establish an idea of whether a commercially off the shelf (COTS) unit can be procured to deliver HEMS functionality, or if further development activities are needed to make this happen.
The conclusion from the evaluation is that existing HEMS systems can offer some of the functionality and have the potential to offer all functionality. However, there is variation between suppliers on the types of functions currently offered and their interfaces. In the next stage of development a more detailed functional requirements specification will be developed based on further development of use cases and the architecture. This will then be used to further evaluate offerings including with a wider product base and then determining integration activities required to ensure the system can be delivered.

5.2 Detailed use cases

Each of the high level use cases will be developed further into detailed use cases which will then determine the functional requirements, information and data interfaces required to deliver each function. These can then be consolidated into a functional specification for the overall system and its subsystems.

5.3 Standards

There are no mandatory standards as such for smart energy design. However, the smart architecture should be proposed to align to best practice, which includes prescribing digital/smart grid standards applicable that help to determine a level of quality sufficient to deliver consumer services.

These should then be explored further to determine design requirements, compatibility and market alignment with current COTS offerings.

Examples of such standards include:

- Cenelec SGAM: Approach to guide the smart system development.
- IEC 61508: Functional safety of electrical/electronic/programmable electronic safety-related systems
- IEC 61850: Power utility automation
- IEC 61968: Common information model (CIM)/distribution management
- IEC 61970: Common information model (CIM)/energy management
- IEC 62056: Data exchange for meter reading, tariff and load control
- IEC 62351: Security
- IEC TR 62357: Reference architecture

In addition the development of standard approaches to IoT standards which are in the pipeline, which may have a market influence on connectivity. These include:

- Matter - An open-source connectivity standard for smart home and IoT (Internet of Things) devices. It aims to improve interoperability and compatibility between different manufacturers and security, and always allows local control as an option. Some of the most prominent names in the digital industry are now proposing to adopt this to ensure interconnectivity and ‘plug and play’ of devices.
- PAS 1878 – This standard has been developed to promote the importance of safe and interoperable energy smart appliances (ESAs). This is particularly important for demand side response (DSR) (i.e. to help reduce peak loads at the local substation/national network) which can form a part of the HEMS system if needed.
- PAS 1879 – This standard builds on PAS 1878 to further define what demand side response is, and sets out what features ESAs should have to allow adequate DSR.

In addition, as the architecture develops consultation will be undertaken with different systems providers to determine how they ensure client satisfaction through a process of quality management.

5.4 Operational governance

Work will be carried out under a sister Pathfinder project to explore the requirements for operational governance which is associated with the interactions between different organisations to deliver the digital service offering. Related to this a digital governance structure will be required which will outline the requirements, controls and processes for managing data and information on the system.

6 Conclusions

This report has outlined how the SLES has been developed, first from an initial concept (or "Level 0" architecture), and then further to a Level 1 architecture.

Schematics have been shown in Figure 3-1 and Figure 3-2 of the different levels of smart system architecture design. The schematics can be developed further to higher levels in future Net Zero Terrace projects. This is likely to be necessary if geographical area of implementation increases since this will result in additional actors and use cases.

In section 2, KPIs that could be applied to the SLES are outlined. These revolve around three underlying themes:
The first theme is the benefits the SLES can bring to the consumer. This results in KPIs 'consumer comfort level', 'affordability' and 'community energy consumption'.
The second theme is the influence of the SLES on the DNO and wider network. This results in KPIs 'satisfaction of DNO 'and 'success of achieving flexibility modes 2-4'.
The final theme is how the SLES's role in reducing carbon consumption. This is present in all KPIs, as the system must be successful to ensure wider roll-out of the NZT scheme.

The system functions and interfaces have been discussed in sections 3.2 to 4.3. Key to understanding these is the idea that components largely fall into two groups. The first is components responsible for a specific location or group e.g. the DNO, a house, the community. The second is components that provide analysis/support and the ability to aggregate and improve operations which may be at a different scale to a single community.

A key piece of learning was the soft market testing working with existing HEMS providers. This demonstrated the viability of HEMS to deliver the functions but also the need to explore integration requirements and further specific functional requirements following further development of the architecture.

Finally, next steps have been laid out, outlining how the SLES development needs to continue. This includes further developing use cases and additional layers of the architecture to deliver the functional requirements specification. Directly working with the supply chain whilst this is being developed will help to evaluate and ensure alignment with the market offerings which will accelerate deployment and de risk the development process. It is also evident that a focus needs to be on standards and prescribing those that we feel the system providers should comply with in addition to determining the overall governance of operation. These will ensure best practice of the system when it is implemented.