Origami

POWER OVER ENERGY

FUSION WP2

Quantifying Flexibility – Combined report v1.9

28 November 2019

1 Executive Summary

The FUSION project will demonstrate the feasibility of geographically local commoditised flexibility, accessible through a universal, standardised market-based framework (the Universal Smart Energy Framework, USEF), to address distribution network congestion issues, and complement national balancing requirements within the existing regulatory framework.

The project trial area of East Fife is defined as the network area supplied by the primary substations at St Andrews and Leuchars. This area was selected because recent increases in both load growth and the integration of distributed generation have led to localised network issues which FUSION is designed to alleviate. FUSION looks to trial the use of commoditised flexibility to supplement, defer or avoid traditional reinforcement. FUSION will also address the challenge of identifying and accessing flexibility through a flexibility market.

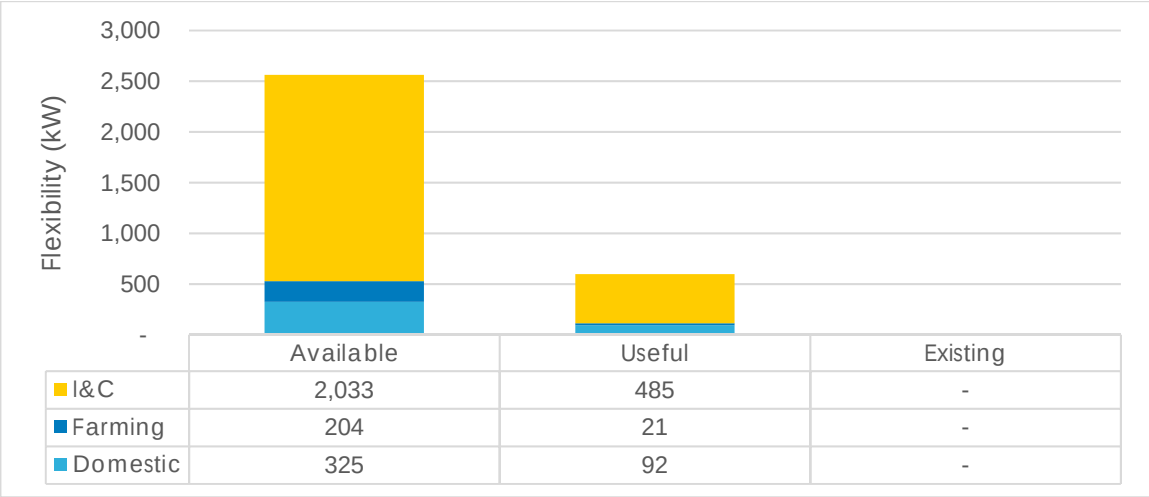
Through the trial in East Fife, FUSION will gain an understanding of the potential use and value of flexibility within geographically local regions to further enhance efficient DNO network management and demonstrate the proof of concept, and evidence the business case, for commoditised flexibility (locally and for GB) through a USEF-based flexibility market.

This report quantifies the flexibility within the study area and brings together the key findings from three sector-specific reports that can be provided on request from fusion@spenergynetworks.com. The report focuses on the following sectors:

- flexibility from the industrial, commercial and SME sectors, prepared by Origami;
- flexibility from the farming sector, prepared by Scottish Agricultural College Consulting; and
- flexibility from the domestic sector, prepared by PassivSystems.

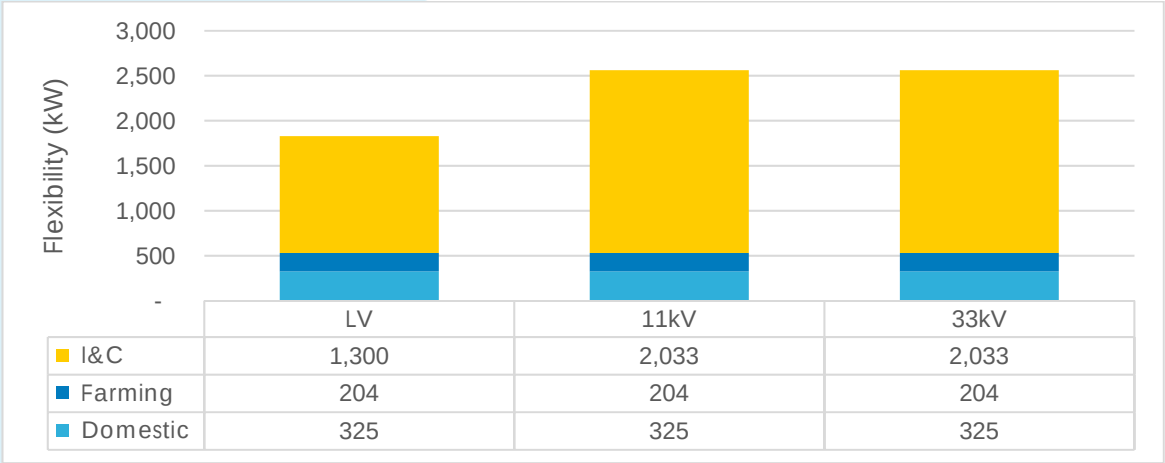
Flexibility is summarised in three categories and illustrated in Figure 1 which uses the following definitions:

- Available – Flexible assets that are not currently being used but which could potentially be used to deliver flexibility services;
- Useful – Available flexibility that is likely to be available to deliver flexibility services, e.g. tea-time flexibility rather than overnight; and
- Existing– flexible assets that are currently providing flexibility;



	Available	Useful	Existing
I&C	2,033	485	-
Farming	204	21	-
Domestic	325	92	-

Figure 1 – Estimated Available, Useful and Existing flexibility from each sector.



	LV	11kV	33kV
I&C	1,300	2,033	2,033
Farming	204	204	204
Domestic	325	325	325

Figure 2 - Cumulative available flexibility per sector across voltage levels.

The possible market value for the estimated total available flexibility per sector is shown in Table 1. The market value comprises; (i) an estimate of the value from non-DSO flexibility services (ranging from DUoS charge avoidance to frequency response services) and (ii) an allowance for flexibility services procured by the DSO to manage network issues.

Table 1 - Possible annual revenue for the available flexibility per sector.

Sector	Available Flexibility (kW)	Annual Flexibility Revenue[1]	Potential Annual Revenue[2]
I&C	2,033	£36 - £89 / kW / year	£73,188 - £180,937
Farming	204	£36 - £89 / kW / year	£7,344- £18,156
Domestic	325	£36 - £89 / kW / year	£11,700 - £28,925

[1] Combining revenue from DSO and non-DSO flexibility services, For details see section 10.2.

[2] Potential Annual Revenue = Available Flexibility (kW) * Annual Flexibility Revenue

Total	2,562	£36 - £89 / kW / year	£92,232- £228,018

Key learning points

Quantifying flexibility

- Within the Project FUSION study area, energy flexibility has been identified in all three sectors[3], from both energy-consuming assets and energy-generating assets.
- 'Available' flexibility has been identified, which could be enabled for the trial. It should be noted however that the enablement may not be commercially viable or may not meet the requirements of the network constraint management service (time of day, magnitude and volume). This would limit the amount of generally available flexibility to that which has been defined as 'useful'.
- The larger the rating of an individual asset and the more energy the asset consumes, the greater the potential for its flexibility. The scale of assets is largest in the I&C sector and smallest in the domestic sector. Therefore, a single asset in the I&C sector will on average have more potential to provide flexibility than a single asset in a domestic property. However, the volume of individual assets in the domestic sector is by far the greatest, when compared to the farming and Industrial, commercial and SME sectors.
- There is potential in all three sectors to access existing energy-generating assets to provide energy flexibility in the project FUSION area. Again, individual asset rating of generation is largest in the industrial, commercial and SME sectors and smallest in the domestic sector. To date the economic drivers for installing generating capacity behind the meter has been strongest in the commercial sectors (I&C and farming) and weakest in the domestic sector.
- Our findings indicate there is a need for investment in new assets to access additional flexibility. In the domestic sector, examples of new assets could include domestic battery storage, EV chargers and intelligent assets e.g. Centrica's hot water tanks and NPG's Customer Led Revolution projects.
- Large energy consumers, particularly in I&C sector, are already performing energy management during peak demand periods in response to incentives and are showing interest in further developing their understanding and use of flexibility.
- Consumers with low energy consumption in each sector are less likely to engage with the flexibility market to provide services. This is due to the weak associated business case compared to that required for deployment at scale and typically a lower familiarity with flexibility and the charges associated with the electricity distribution system in general.

[3] Industrial, commercial and SME sector, farming sector and domestic sector.

Challenges

- The findings indicate that effective and successful engagement with customers requires an existing relationship, and existing customer knowledge of flexibility is relatively low.
- Customer data is a key component in estimating potential flexibility and there has been very limited customer data made available to date.
- The East Fife area is generally more affluent than the remainder of Fife with a population of more than 22,000 that is reliant on tourism and education as there is no significant manufacturing or production capability. As a consequence, there are fewer opportunities to fund new flexible assets in the domestic sector, limiting the opportunity for flexibility.
- In the Farming and I&C sectors, connecting existing energy-consuming assets to an intelligent Building Management System (BMS) and installing new energy-generating assets behind the meter could provide increased flexibility, but this would have a cost associated as the existing BMS may need to be upgraded before it can be used to provide flexible loads.
- The potential for individual customers to provide flexibility is particularly low in the domestic sector compared to other sectors. The financial reward (and hence the associated incentives) for an individual domestic consumer to provide flexibility is also proportionately small.
- The findings indicate there is no natural leading counter-party to connect/offer/link flexibility providers with the DSO. From a commercial point of view, it would appear the Aggregator is;
  - the party with the highest involvement and with the fewest resources (technical, commercial and financial) and
  - the only one that 'needs' the connection to happen[4].
- It must be noted that the Universal Smart Energy Framework (USEF) sets standards and definitions for functions and market actors. Therefore, the role of Aggregator as defined by USEF is not the UK Aggregator as it is typically understood. Rather, it is an aggregation function which can be undertaken by any of the market actors.
- Further challenges to enabling flexibility:

Technical Challenges	Commercial Challenges
▪ Secure protocol ▪ Speed of equipment response ▪ Flexibility's effect on core activity ▪ Establishment and maintenance of	▪ Cost of any required installation and integration of flex' assets and their associated communications/control infrastructure. ▪ Validation and billing processes. ▪ Cost benefit analysis for each participant in the chain of enabling

[4] For the other commercial counter-parties, at this stage it is a 'nice to have' not seen as a must have solution due to the maturity (both commercial and financial) of the flexibility market at the DSO level and the understanding/trust in the DSO flexibility market from the other commercial counter-parties.

Technical Challenges	Commercial Challenges
communication between Aggregators and the Prosumers' equipment ▪ Provision of an acceptable Base-Load to use as a reference point for measuring the changes resulting from intervention.	and utilising flexibility due to restrictions on confidentiality and commercial sensitivity, and complexity of the chain. ▪ Relative commercial importance and interest to each participant in the study in the context of the overall revenue and the energy expenditure. ▪ Viability of contractual set-up between parties ▪ Time required to agree commercial T&Cs

Limitations of the study

- Energy usage data for the I&C and domestic sectors within the East Fife area is sparse. Existing datasets are often out of date and they are often either;
  - not location-specific or
  - require written permission from the data proprietor before they can be shared (as per data protection policy).
- Using anonymised data sources to quantify flexibility at the higher level of aggregation prevents identifying individual customers.
- Assumptions were required to account for the limited available data that could lead to an overestimation of the level of flexibility in the FUSION area (e.g. there may have been sources of flexibility that were included in the estimation but are reserved for ancillary services and not accessible).

Version	Date	Notes	Created	Reviewed
0.1 to 0.11	01-May-19 to 12-Oct-19	Creation of first full draft	TY / PP / BS	DM
1.0	13-Oct-19	First full draft for SPEN review (subject to formatting, completion of some graphs and final Origami review)	Origami	N/A
1.1 to 1.6	22-Nov-19	Applying corrections in response to Comments from SPEN	Origami	DM
1.7	25-Nov-19	Revisions based on comments from SPEN	Origami	DM
1.8	26-Nov-19	Revisions based on comments from SPEN	Origami	DM
1.9	28-Nov-19	Final revisions	Origami	DM

Approval

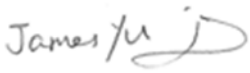
Name	Position	Date	Signature
James Yu	Future Networks Manager	28/11/2019	

Table of Contents

Table of Tables

Table of Figures

Glossary

CHP	Combined Heat and Power	MW	Mega Watt
CLNR	Customer Led Network Revolution	NIC	Network Innovation Competition
DNO	Distribution Network Operator	NTVV	New Thames Valley Vision
DSO	Distribution System Operator	ONS	Office for National Statistics
DUoS	Distribution Use of System Charges	PV	Photo-Voltaic
EPC	Energy Performance Certificate	SIC	Standard Industry Classification
ESO	Electricity System Operator	SME	Small and Medium Enterprise
EV	Electric Vehicle	SPEN	SP Energy Networks
FFR	Firm Frequency Response	STOD	Seasonal Time of Day
GIS	Geographical Information System	STOR	Short-Term Operating Reserve
GSHP	Ground Source Heat Pump	UKPN	UK Power Networks
HMRC	Her Majesty's Revenue and Customs	UMV	Utility Map Viewer
IDBR	Inter-Departmental Business Register	UPS	Uninterruptable Power Supply
LCT	Low Carbon Technologies	USEF	Universal Smart Energy Framework
LF	Load Factor	WD	Weekday
MD	Maximum Demand	WE	Weekend
MVAr	Mega Volt-Ampere Reactive		

2 Introduction

This report quantifies the available flexibility in the Project FUSION study area of East Fife. It does do by compiling the findings of three separate sector-specific reports, which respectively quantified the following:

- flexibility from industrial, commercial and SME sectors, prepared by Origami.
- flexibility from farming sector, prepared by Scottish Agricultural College Consultancy; and
- flexibility from domestic sector, prepared by PassivSystems;

2.1 FUSION project

FUSION is a £5.67 million innovation project funded under Ofgem's 2017 Network Innovation Competition (NIC). It is to be delivered by SP Energy Networks in partnership with seven project partners: DNV GL, Origami, PassivSystems, Imperial College London (academic partner), SACC, The University of St. Andrews, and Fife Council.

FUSION will demonstrate the feasibility of delivering a local, commoditised flexibility market, which is accessible through a universal, standardised market-based framework (USEF[5]), to address distribution network congestion issues, and complement national balancing requirements within the existing regulatory framework. FUSION aims to achieve the following objectives:

- Evaluate the feasibility, costs and benefits of implementing a common flexibility market framework based on the open 'USEF' model to manage local distribution network constraints and support wider national network balancing requirements.
- Investigate a range of commercial mechanisms to encourage flexibility from energy consumers' use of multi-vector electrical applications in satisfying overall energy use.
- Conduct live trials in the East Fife area to gain an understanding of the potential use and value of flexibility within geographically local regions to further enhance efficient network management and demonstrate the business case of trading commoditised flexibility (locally and for GB) through a USEF-based flexibility market.

If successfully rolled out across GB, the FUSION concept could save customers over £236m, in addition to 3.6m tCO_2 by 2050[6]. These savings would be higher if the more ambitious 'net zero' scenario being considered by the Advisory Group on the Costs and Benefits of Net Zero[7] were to be implemented.

[5] the 'Universal Smart Energy Framework'

[6] Electricity NIC submission: SP Energy Networks – FUSION, 30 November 2017; https://www.ofgem.gov.uk/system/files/docs/2017/11/fusion_-_fsp_redacted_29_11_2017.pdf

[7] "Net Zero The UK's contribution to stopping global warming", Committee on Climate Change, May 2019

2.2 Need for flexibility

Load growth through the electrification of transport and heat and the integration of low carbon technologies (LCTs) brings challenges and opportunities for the DNOs.

The key challenge is to ensure that distribution networks are operated safely and deliver a cost-effective service for connected customers, whilst allowing for the growth of distributed and intermittent generation and supporting customers during the transition to a low carbon economy.

The opportunity is to utilise existing or new flexible assets connected to the distribution network to manage system needs (particularly technical constraints) and support the transition from a reactive DNO system (designed to distribute electricity from higher voltages to lower voltages), towards a distribution system operator (DSO) model that proactively manages the energy flows within the distribution network that vary in direction multiple times within every day.

Flexibility is defined as "the ability to modify generation and/or consumption patterns in reaction to an external signal (such as a change in price, or a message)[8]. Embedded flexibility is flexibility located behind the meter and connected directly to the distribution grid that could provide one or more flexibility services to support the grid, whether locally, regionally, or nationally.[9]

[8] "A Smart, Flexible Energy System - A call for evidence", BEIS and Ofgem, November 2016

[9] "Embedded generation and embedded benefits", Guidance Note, Elexon, https://www.elexon.co.uk/documents/training-guidance/bsc-guidance-notes/embedded-generation-and-embedded-benefits/

3 Overview of East Fife and the scope of flexibility assessment

SP Energy Networks defines the geographic area targeted by project FUSION as that area supplied by the primary substations at St Andrews and Leuchars. This is not an area recognised by any other source considered by this study, so this section considers these differences to make use of publicly available data and information.

3.1 Overview of the East Fife area

The East Fife area is an area within the North East Fife parliamentary constituency and covers most of the east coast of Fife. Figure 3 shows the FUSION study area overlaid over the map of North East Fife parliamentary constituency. Additional and detailed comparison is presented in Customers in the area

The North East Fife parliamentary constituency area is much less reliant on manufacturing and heavy industry than other areas of Fife and is characterised by rural, agricultural and fishing industries, together with tourism in the East Neuk and St Andrews. The following sections summarise the composition of customers for each sector.

3.1.1 Industrial, commercial and SME sectors

Data for businesses in North East Fife parliamentary constituency area is available from Her Majesty's Revenue and Customs (HMRC) and the Inter-Departmental Business Register (IDBR) published by the Office for National Statistics (ONS). Both HMRC and IDBR cover a wide range of businesses from single-employee companies to multi-national companies and are based on the registered business address. This data is summarised in Figure 4 and the analysis includes agricultural, forestry and fishing businesses (to represent all businesses in the North East Fife parliamentary constituency area). Over 70% of 2,630 registered businesses within the area are represented by six sectors (Professional, scientific & technical; Retail; Accommodation & food services; Construction; Arts, entertainment, recreation & other services; and Business administration & support services).

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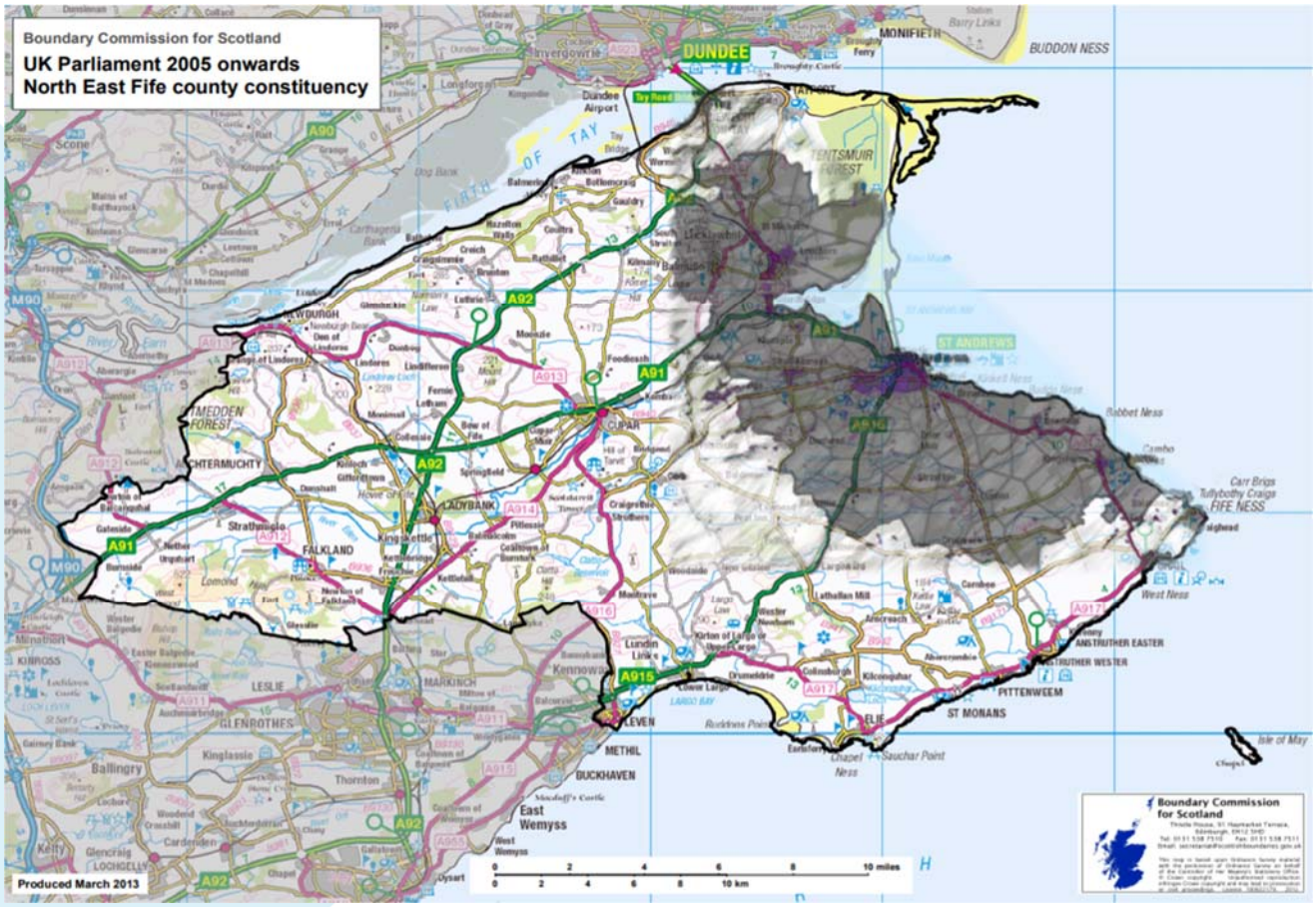

Figure 3 - Comparison of the East Fife area (FUSION Study area, shaded in dark grey) with North East Fife parliamentary constituency[10].

[10] http://www.bcomm-scotland.independent.gov.uk/maps/westminster/2005/

Table 2 - Comparison of North East Fife parliamentary constituency and the East Fife area.

Factor	North East Fife Parliamentary Constituency	East Fife Area
Population	73,405[11] (includes population of East Fife area)	22,180[12] (30.2% of North East Fife parliamentary constituency)
Description of the area	the parliamentary constituency of North East Fife	area supplied by St Andrews and Leuchars primary substations
Area	778km^2 (includes East Fife area)	137km^2 (17.6% of North East Fife parliamentary constituency)
Population Density	80 people/km^2 (excluding the East Fife area) 94 people/km^2 (including the East Fife area)	162 people/km^2 (>2 x remainder of North East Fife parliamentary constituency)
Main population centres	Anstruther, Crossford, Cupar, Kennoway, **Leuchars**, Leven, Newport-on-Tay, and **St Andrews,** Tayport.	Guardbridge, **Leuchars, St Andrews** and Strathkinness**.**
Remainder of area	▪ sparsely populated small villages; ▪ recreational areas; and ▪ farms and rural areas.	▪ sparsely populated small villages; ▪ recreational areas; and ▪ farms and rural areas.

3.2 Customers in the area

The North East Fife parliamentary constituency area is much less reliant on manufacturing and heavy industry than other areas of Fife and is characterised by rural, agricultural and fishing industries, together with tourism in the East Neuk and St Andrews. The following sections summarise the composition of customers for each sector.

3.2.1 Industrial, commercial and SME sectors

Data for businesses in North East Fife parliamentary constituency area is available from Her Majesty's Revenue and Customs (HMRC) and the Inter-Departmental Business Register (IDBR) published by the Office for National Statistics (ONS). Both HMRC and IDBR cover a wide range of businesses from single-employee companies to multi-national companies and are based on the registered business address. This data is summarised in Figure 4 and the analysis

[11] https://our.fife.scot/northeastfife/

[12] https://www.citypopulation.de/en/uk/scotland/; St. Andrews: 17,580, Leuchars: 2,300, Guardbridge:750, Strathkinness: 800, (2016 estimate)

includes agricultural, forestry and fishing businesses (to represent all businesses in the North East Fife parliamentary constituency area). Over 70% of 2,630 registered businesses within the area are represented by six sectors (Professional, scientific & technical; Retail; Accommodation & food services; Construction; Arts, entertainment, recreation & other services; and Business administration & support services).

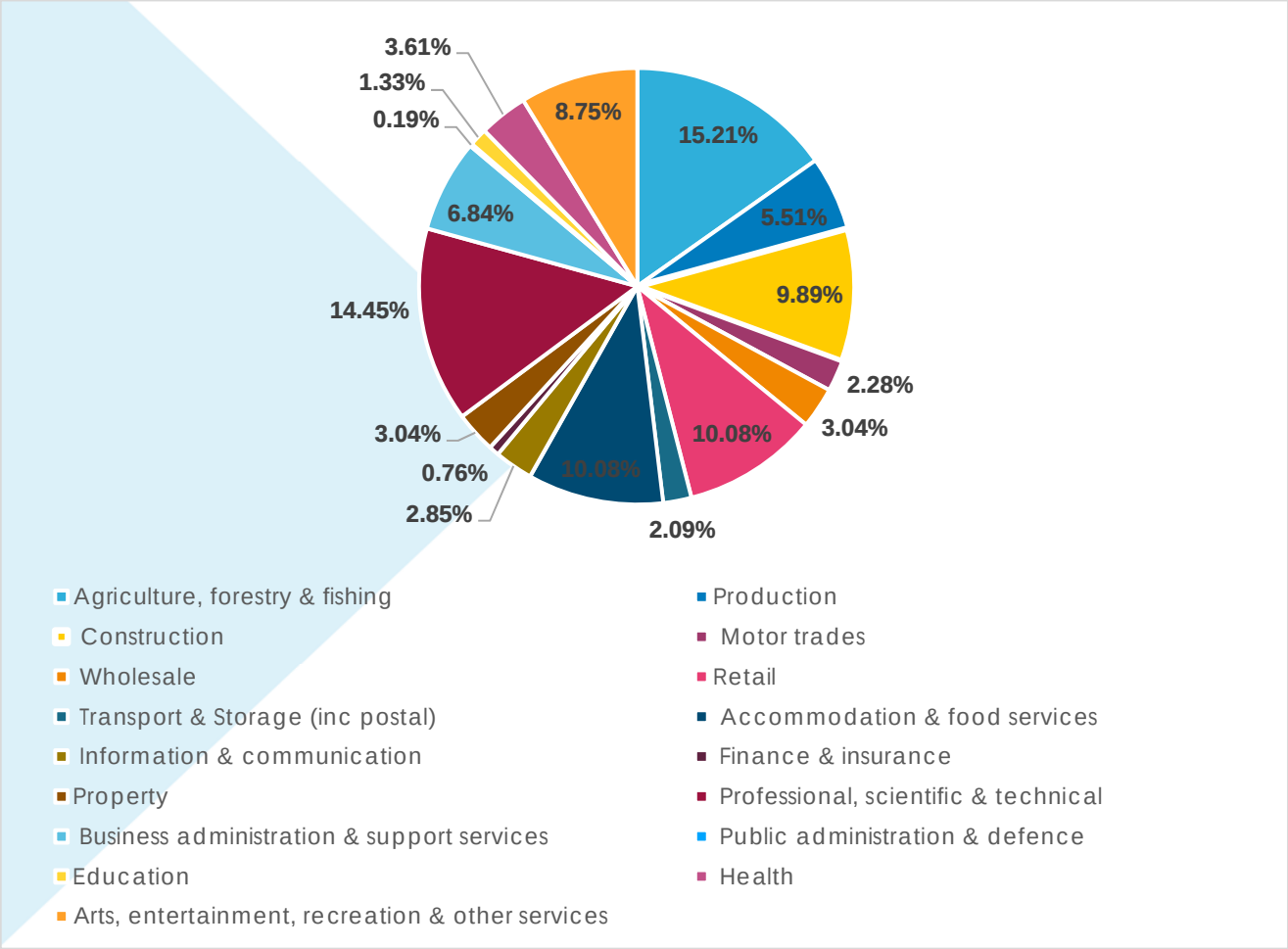

Figure 4 - Distribution of businesses in North East Fife Parliamentary Constituency Area[13].

3.2.2 Farming customers

In terms of farming, the East Fife area:

- comprises ~41,000 hectares of agricultural land of which ~19,000 hectares are cereals and the remaining ~22,000 hectares are split between other crops such as potatoes, vegetables, soft fruit, grazing and woodland (see Table *3* for further details);

[13] Source: Table 6 - Number of VAT and/or PAYE based enterprises by Parliamentary Constituency and broad industry group (ONS Business count) https://www.ons.gov.uk/businessindustryandtrade/business/activitysizeandlocation/datasets/ukbusinessactivitysizeandlocation

- is a significant producer of soft fruit (~12% of the Scottish total) and vegetables (~9% of the Scottish total); and
- has a nationally insignificant proportion of livestock numbers with the exception of broiler (meat) chickens (~7% of the Scottish total).

Table 3 - Agricultural crop areas in East Fife[14]

Crops and land use	Edina Agcensus 2015 (hectare)	SG June Census 2016 (hectare)	East Fife vs Scotland (%)
Cereals	19,356	432,091	4%
Oilseeds	1,254	30,731	4%
Pulses	250	3,777	7%
Potatoes	1,298	27,525	5%
Vegetables	1,592	18,168	9%
Soft fruit	224	1,878	12%
Forage crops	217	16,460	1%
Grass	10,666	1,327,934	1%
Rough grazing	711	3,084,581	0%
Woodland	2,269	502,399	0%
Fallow	0	43,008	0%
Total crops, grass and fallow	36,310	1,910,177	2%
Total agricultural area	**41,160**	**5,652,152**	**1%**

3.2.3 Domestic customers

3.3 Data regarding the domestic population of the FUSION Project area was made available from public sources such as Fife Council's Tayplan, census information and reports commissioned on the housing needs in Fife. As described in Customers in the area

The North East Fife parliamentary constituency area is much less reliant on manufacturing and heavy industry than other areas of Fife and is characterised by rural, agricultural and fishing industries, together with tourism in the East Neuk and St Andrews. The following sections summarise the composition of customers for each sector.

3.3.1 Industrial, commercial and SME sectors

[14] Scottish Government 2015 June Agricultural census, SAC Consulting

Data for businesses in North East Fife parliamentary constituency area is available from Her Majesty's Revenue and Customs (HMRC) and the Inter-Departmental Business Register (IDBR) published by the Office for National Statistics (ONS). Both HMRC and IDBR cover a wide range of businesses from single-employee companies to multi-national companies and are based on the registered business address. This data is summarised in Figure 4 and the analysis includes agricultural, forestry and fishing businesses (to represent all businesses in the North East Fife parliamentary constituency area). Over 70% of 2,630 registered businesses within the area are represented by six sectors (Professional, scientific & technical; Retail; Accommodation & food services; Construction; Arts, entertainment, recreation & other services; and Business administration & support services).

above, there Is a small number of population centres across the project area. The majority of the residents in St. Andrews (with the exception of the student population) are owner occupiers with the remainder being made up of the private and social rental sector. Almost 40% of residents in the town live in a two-person household, a higher rate than in both Fife (36.6%) and Scotland (34%). There is a lower rate of single occupancy households, 27.8% in St Andrews compared with 31.8% across Fife and 34.7% across Scotland. In addition, there is a slightly higher rate of 'four persons households'; 12.2% compared with 11.6% in Fife and 11.5% in Scotland. Breakdown by housing type in St. Andrews area is presented in Figure *5*.

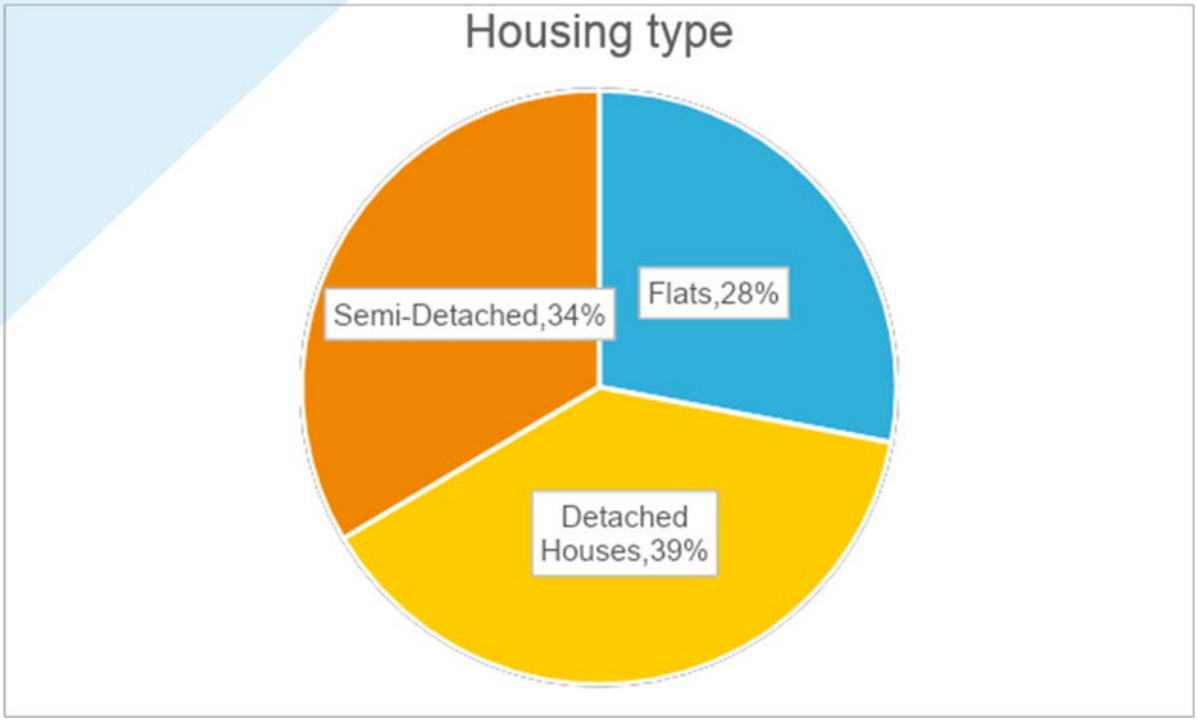

Figure 5 - Housing types in St. Andrews.

Guardbridge is currently a village of c300[15] homes however it is also the site of the new University of St Andrew's Eden Campus. The Eden Campus[16] will accommodate 450 members of staff and will support research and development into low carbon technologies. A new housing development is also planned for the Guardbridge area which will double the population. The overall population within the FUSION study area is expected to grow over the next ten years. The majority of households in the study area are owner occupied (60%), which means that they will have the autonomy to potentially enter into contracts with SP Energy Networks to provide flexibility services. Owner occupiers also have the ability to choose to invest in low carbon technologies either by using their own finances or by securing an interest-free loan from Local Energy Scotland.

3.4 Electricity Supply to the East Fife Area

The distribution network for the East Fife area is detailed in Figures 6 and 7 with the area supplied as follows:

- the transmission network via SP Transmission 275/132kV substations at Mossmorran and Westfield;
- the EHV distribution system via SP Energy Network 132/33kV substation at Cupar; and
- the HV distribution system via SP Energy Network 33/11kV primary substations at St Andrews and Leuchars.

[15] 2011 Census

[16] https://www.st-andrews.ac.uk/about/sustainability/eden-campus/site/

Figure 6 - SP Energy Networks 33/11kV Substations in the North East Fife area

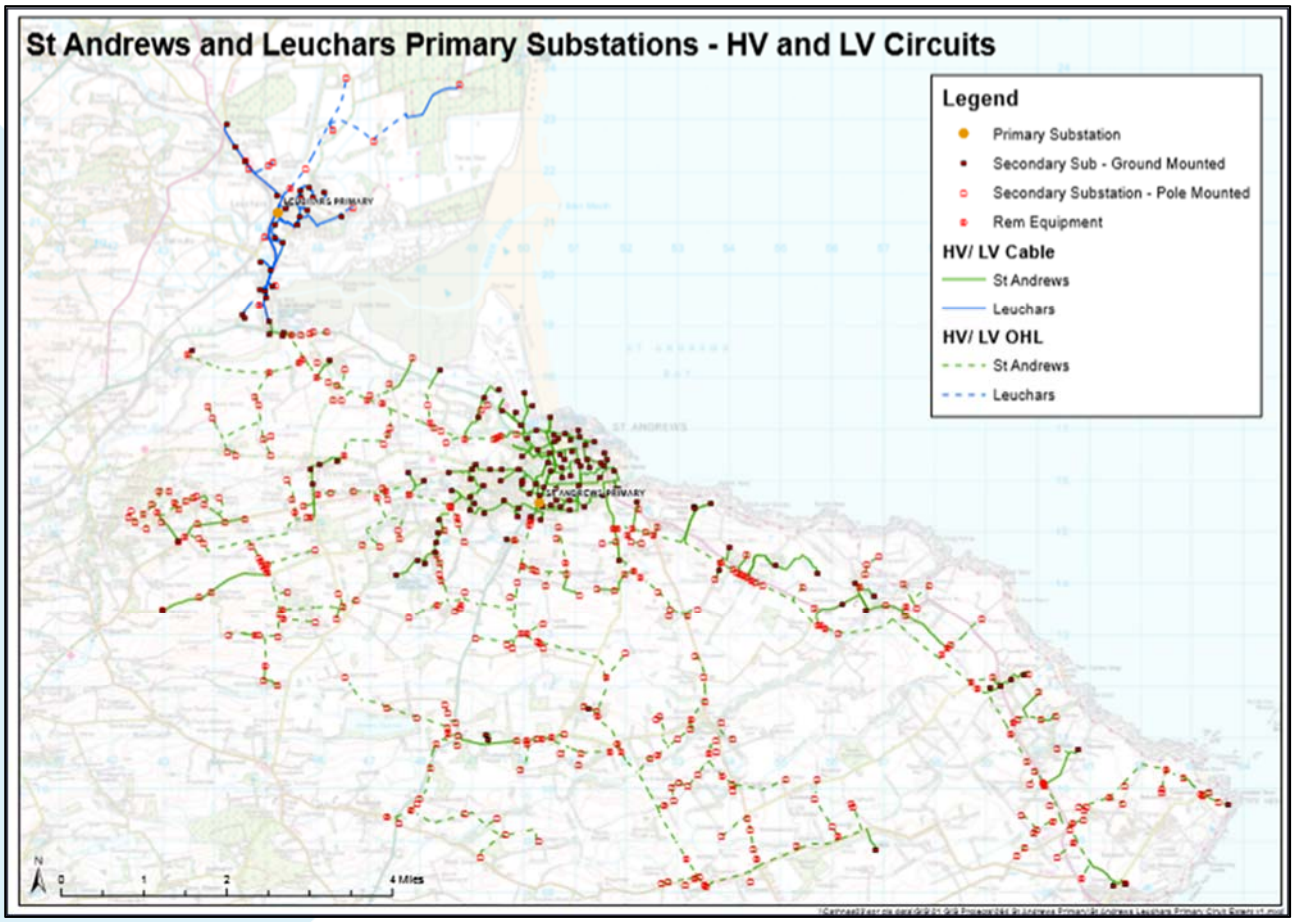

Figure 7 - SP Energy Networks 11kV & Low Voltage Network in the East Fife area.

Table 4 - Peak Capacity and Demand in the East Fife Area[17]

Primary Substation	Firm Capacity (MVA)	Peak Demand (2018, MVA)	Spare Capacity (MVA)
St Andrews	24.0	22.94 (83.3%)	1.06 (4.4%)
Leuchars	10.5	7.68 (81.0%)	2.82 (26.9%)

As can be seen from Table *4*, the two primary substations are well-loaded at peak with only limited capacity available for new connections and demand growth. SP Energy Networks completed a large reinforcement project in early 2019 at Cupar 132/33kV Grid substation including a new 11kV Switchboard and new 33/11kV T1 and T2 transformers. The East Fife area is experiencing a large increase in demand (largely from new businesses in the area) and from an increase in the number of applications for the connection of new low carbon generation at both 33kV and 11kV. Flexibility services could provide an alternative to further reinforcement.

[17] Capacity/ Demand Information: from SP Energy Networks' Long Term Development Statement https://www.spenergynetworks.co.uk/pages/long_term_development_statement.aspx

4 Quantification Methodology

Flexibility is categorised in this report as:

Flexibility Type	Description
Existing	Flexibility that exists today that is being utilised (regardless of its suitability for any flexibility service);
Available	Existing flexibility and flexibility that is not currently being used but which could potentially be used to deliver flexibility services
Useful	Available flexibility that is likely to be available when required to deliver flexibility services, e.g. tea-time flexibility rather than overnight;
Future	Flexibility yet to be built where the capacity and suitability may be unknown

Quantification of flexibility in the East Fife area and the flexibility services that could be supported requires understanding of the customers connected to the local distribution network and determining the available local flexible resources. The methodology for quantifying flexibility for the three sectors can be split into the following steps:

Whilst all three studies considered the above steps, sector-specific methodologies varied, and these are considered further in this Section 4.

4.1 Industrial, commercial and SME sectors

Given the number and diversity of businesses in the East Fife area, the tight control of data due to privacy concerns and general availability of data, the following process was developed to help quantify flexibility from non-domestic and non-agricultural customers.

4.1.1 Data availability and customer selection

This stage reviewed available data sources and publicly available information for customers in the East Fife area and the completeness of the data was assessed though engagement with SP Energy Networks and project partners.

The tiered approach to identifying target businesses, shown in Figure *8*, starts with a review of the sectors for all businesses in North East Fife parliamentary constituency which is summarised in section Industrial, commercial and SME sectors3.2.1. There are four successive steps:

a. identify the sectors that exist in the East Fife area through understanding typical businesses and an analysis of existing data sources and other sources of information.

b. develop a ranking methodology to identify target sectors in the East Fife area based on; the presence of suitable technology to provide flexibility, the ability of the flexibility to provide one or more flexibility services, and the availability of appropriate data.

c. apply the ranking methodology to identify target business types in the East Fife area; and

d. identify target businesses to conduct site surveys which includes unique major customers and businesses that are representative of those in the East Fife area.

Figure 8 - Hierarchy for selecting representative businesses.

4.1.2 Flexibility evaluation

Review available data resources to determine what quantification methodology can be applied and the degree of confidence in the outcome. Table 5 provides a summary for each methodology and suitability for the desktop study.

Table 5 - Proposed methodology types for quantifying flexibility

Methodology	Description	Data pre-requisite
Postcode analysis	Combine GIS network topology with information on business types and Energy Performance Certificates (EPCs) for commercial customers (where available) then apply typical flexibility indices and assumptions associated with the type of business to estimate the available flexibility in each postcode area of the East Fife area.	SIC data and EPCs per postcode
Primary substation demand	Use the Origami FlexFinder tool to analyse demand at selected substations to provide an estimate of the aggregated flexibility for each primary substation.	Time series data for St. Andrews and Leuchars primary substation
Profile Class analysis	Analyse Elexon Profile Class data to infer typical demand profiles for customers in FUSION on a seasonal time of day basis (STOD) and estimate the available flexibility using typical flexibility indices and assumptions linked to business types.	Number of customers per profile class per feeder and their associated type of business
Anonymised half-hourly and non-half-hourly demand	Use the Origami FlexFinder tool to analyse half-hourly demand data for selected customers (subject to data availability) and apply typical flexibility indices and assumptions linked to business types. Analyse data for non-half-hourly customers as per methodology 3 above.	Access to anonymised information for customer in East Fife area

Methodology	Description	Data pre-requisite
Non-half-hourly demand / generation attributed to customer	Apply corresponding flexibility Indicators to estimate non-half-hourly customers. Analyse generation data provided separately to understand load factor, availability and reliance.	List of businesses inside the East Fife area
Half-hourly demand from named customers	Use the Origami FlexFinder tool to analyse half-hourly demand data and apply typical flexibility indices for business types. Consider businesses for site survey of selected sites to identify size and suitability of the assets.	Year-long half-hourly demand data.

Each methodology has a different confidence level based on the granularity of the data available and the assumptions that will affect the forecast level of flexibility in the desktop study. Table *6* summarises how the data available for each methodology affects the confidence level of the flexibility predicted/quantified.

Table 6 - Overall confidence of outcome for each flexibility analysis methodology.

Methodology	Quantification Level[18]					Overall Confidence of outcome
	Primary substation	Customer voltage	Customer sector	Asset type (G, D, S)[19]	Asset size	
1. Postcode analysis	H	M	M	L	L	L
2. Primary substation HH demand	H	M	L	L	L	L
3. Profile class analysis	M	M	L	M	L	L
4. Anonymised HH and nHH demand	M	M	M	M	L	L
5. nHH demand attributed to customer	H	H	H	M	M	M
6. HH demand	H	H	H	H	H	H

[18] Quantification Level and Overall Confidence of outcome is categorised as; high (H), medium (M) or low (L).

[19] Flexible asset type could be generation (G), demand (D) or energy storage (S).

Methodology	Quantification Level[18]					Overall Confidence of outcome
	Primary substation	Customer voltage	Customer sector	Asset type (G, D, S)[19]	Asset size	
from named customers						

Across all of the methodologies applied, the assumptions and sites surveyed mean that, whilst the methodology is rigorous in identifying flexibility, there may have been sources of flexibility that were included in the estimation but are not accessible, e.g. flexibility reserved for ancillary services or domestic storage heating controlled by tele-switching. This could lead to an overestimation of the level of flexibility in the FUSION area.

4.1.3 Site survey

The objective of the site survey is to determine the flexibility available at the site and the acceptability of using the flexibility. This will also capture information on the operating regimes (seasonal, day of week and time of day) and the flexibility capacity.

A structured approach was adopted for each site visit, including the following steps:

- Introduction to FUSION and outline the objectives of the visit;
- Get an overview of the potential sources of flexibility at the site:
  - Heating source and the control configuration;
  - Generation assets (including standby generation) and their standard operating procedures and maintenance;
  - Details of any Uninterruptable Power Supplies (UPS) and their supported demand;
  - Other significant consuming units and their standard operating procedures; and
  - Distribution of operating regimes between peak and off-peak demand;
- Visit the identified assets of interest to capture technical information and clarify operational constraints; and
- Summarise the findings to the hosting organisation.

The study involved a review of the potential flexibility at six customer sites that were representative of typical customers within the East Fife area and to use the information collected to validate and support assumptions made in relation to other customers.

4.1.4 Extrapolation

The flexibility estimates determined from analysis and site visits are used to determine the flexibility from non-domestic and non-farming customers within the entire FUSION study area. The level of certainty will vary as the level of confidence varies from sites that have been surveyed (highest level of confidence) to sites where there is little or no data

(lowest level of confidence). Confidence of outcome is largely driven by the availability of information on energy usage and potential sources of flexibility, with low availability of data limiting the accuracy of flexibility estimates. In addition, businesses will naturally vary through size and composition of the equipment, e.g. the flexibility of two similar hotels could vary if one has a spa and the other does not. The methodologies for extrapolation are summarised in Table *7*.

Table 7 - Extrapolation method for each category of site.

Category of Site	Extrapolation methodology
sites that have been visited	use the estimated flexibility determined during the site visit to determine a STOD profile for flexibility.
sites similar to those visited	apply the estimated flexibility determined during site visits to all similar sites, making suitable allowance for the relative size of businesses to determine a STOD profile of flexibility.
half-hourly sites analysed using the FlexFinder tool	use the flexibility determined by the FlexFinder tool together with any experience and / or understanding of that business type to estimate any additional flexibility to determine a STOD profile of flexibility for that business.
sites that are unique where there is a lot of data	analyse the data available in light of publicly available knowledge and use experience and / or understanding of that business type to estimate any additional flexibility to determine a STOD profile of flexibility for that business.
non-half-hourly metered customers where there is a lot of data	analyse the data available in light of publicly available knowledge and use experience and / or understanding of that business type to estimate any additional flexibility to infer a STOD profile of flexibility for that business.
other sites where there is little or no data	use experience and / or understanding of that business type to estimate any additional flexibility and infer a STOD profile of flexibility for that business.

4.2 Farming sector

In order to establish an overall picture of the agricultural businesses within the East Fife area network maps were obtained from SP Energy Networks. Reference to these maps showed that the boundary between properties supplied by the branches of the distribution network that are included in the study and those supplied from other primary substations was complex. It could therefore not be assumed that crops grown, and livestock reared within the boundaries of the East Fife area would necessarily be served by electricity supplies from the relevant network branch. Further, two surveys were applied to identify premises representative of the sector and suitable for site visits.

4.2.1 Stage 1 survey

The combination of examining Ordnance Survey maps and discussions with existing contacts in the farming community allowed businesses that were no longer involved in farming to be excluded from further assessment. The remaining businesses were further examined to ensure they were supplied from the East Fife distribution network and whether significant agricultural activity is conducted at the location. The list was further refined to remove farm premises where

the land is mainly pasture or sub-let to third parties as the electricity demand would be more representative of domestic premises with minimal additional agricultural loads.

4.2.2 Stage 2 survey

The remaining shortlisted premises were selected for a stage 2 survey to determine the main enterprises on the farm, the main uses of electricity at your site and whether there was any generation on site (renewable or standby).

Where information was not given or not available, mapping data, aerial photography, publicly available information and the local knowledge of SACC was used. Missing information on electricity consumption and the type of assets presented at the farm was populated during site surveys.

Only those farms with a significant involvement in at least one of the identified enterprise types or with on-site generation were considered suitable candidates for detailed study. From this list of suitable candidates, the final selection was made to ensure that all of the relevant activities were covered and following confirmation that the selected farmers were willing to participate in the study.

4.2.3 Site survey

As well as filling in the gaps in stage 2 surveys, site surveys were used to identify suitable assets for flexibility and understand their operating schedule. Where existing site metering or extrapolation methods were insufficient to enable an adequate breakdown by use, SACC conducted further investigations including the temporary metering to assess power usage of specific equipment. Many farm demands are seasonal, and quantification of this seasonality has been an important aspect of the surveys

4.2.4 Extrapolation

Analysis of the data gained from the surveys of all types was used to assign each enterprise to one of six electricity profiles which was then used to extrapolate the flexibility likely to be available across the FUSION study area. With a lack of measured full profile data, we needed to make estimations to build these profiles using one or more of the following estimation methods:

- scale (tonnage or number of animals): extrapolation of benchmarked power consumption data, adjusts for season and corresponding estimate of throughput per day/week/month;
- composition of assets (e.g. refrigeration or ventilation), seasonally adjusted based on local weather data, local daylight times;
- building envelope heat loss/gain assessment seasonally adjusted based on local weather data; and
- process usage as drying and pumping, equipment power specification and control ability (modulation), combined with a production profile.

4.3 Domestic sector

Unlike the customers in the farming and the I&C sector, the domestic sector presents a unique challenge due to its size, commercial awareness and diversity of the customers.

4.3.1 Data availability and customer selection

The initial desktop study research conducted by Passiv reviewed a number of publicly available data sets to ascertain the current capacity and metrics related to domestic renewable energy installations in the East Fife area. These sources included:

- The Fife Local Development Plan;
- Ofgem Quarterly Feed-in Tariff Statistics;
- The Renewable Energy Database;
- The BEIS Renewable Energy Planning Database;
- The National Statistics Department Solar Voltaic Deployment Report;
- The Sub Regional Feed-in Tariffs Confirmed on the Central Fit's Register Report;
- The Energy Savings Trust Green Homes Database;
- Chargeplace Scotland; and
- ZapMap.

Reviewing the available data sources gives enough information to build a view of the typical demographics of the population and the domestic energy landscape in the FUSION study area. This information includes the distribution of tenure and property types in the area, which can be used to infer suitability for deploying LCT and flexible assets in the area. Existing installations of LCTs are estimated from data gathered from the governmental and environmental charity databases. The dominant LCT deployed across the FUSION area in domestic homes is Solar PV, driven by the financial incentive provided by the Feed in Tariff.

4.3.2 Customer survey

Building on the available data, several stakeholder groups were identified and selected for further engagement. Additional information was gathered through interviews with individual domestic customers identified at stakeholder engagement events and newsletters shared via University of St. Andrews staff network, Fife Council, local charities, volunteer organisations and housing developers. The objective of these interviews was to gather Information about the household relating to energy use (e.g. insulation, presence of smart meter or low carbon technology), attitude towards the project and sustainability in general.

The methodology for assessing domestic flexibility availability in the East Fife area included a consideration of the following factors:

- the pervasion of assets and consumer adoption supporting metering and tariff structures;
- the ability of different domestic assets and control regimes to meaningfully participate in a USEF market; and
- the appropriate categorisation methodology for flexibility, largely Existing Flexibility and Future Flexibility.

4.3.3 Flexibility evaluation

Combining information from the customer surveys and public information on total LCT installation in the area provides an estimate of exiting flexible assets (e.g. air source and ground source heat pumps and overnight storage heaters). Findings are referred to from previous innovation and research projects to associate the level of flexibility for these assets and potential for future flexibility.

5 Desktop evaluation of flexibility

The desktop evaluation of flexibility provides an overview of findings from analysis and other information provided by SP Energy Networks and project partners.

5.1 Industrial, commercial and SME sectors

Whilst all of the businesses in the East Fife area are customers of SP Energy Networks, not all of them have an active relationship with SP Energy Networks and even where the relationship exists, any information about the customer cannot be shared by SP Energy Networks without prior written consent. To compensate for limited availability of data directly from customers or from SP Energy Networks, publicly available data sources were reviewed and analysed. This section provides a summary of the findings from the desktop analysis for non-domestic and non-farming customers.

Analysis of the ~600 postcodes supplied within the East Fife area were used to identify customers and conduct analysis using the available Energy Performance Certificates (EPCs) for non-domestic properties to estimate potential flexibility per building use class. Table *8* provides the aggregated estimated flexibility from assumed nominal load for electric heating (winter flexibility), air conditioning (Summer flexibility) and refrigeration (all year-round average flexibility). Most of the estimated flexibility from EPCs is located across St. Andrews.

Table 8 - Aggregated estimated flexibility from non-domestic EPCs per building use class available for properties in the FUSION study area.

Building Use class	Estimated available flexibility (kW)		
	Winter HVAC	Summer HVAC	Chillers/ Refrigeration
Education	0.0	0.0	0.5
Emergency Service	0.0	0.0	2.3
General Assembly/Leisure	10.4	9.6	342.0
Retail/Financial	83.5	20.1	86.7
Office/Workshop	25.5	0.9	8.9
Hotel	30.3	333.6	83.5
Restaurant/Cafes/Takeaway	16.5	3.3	90.6
Storage/Distribution	1.5	0.0	0.0

Building Use class	Estimated available flexibility (kW)		
	Winter HVAC	Summer HVAC	Chillers/ Refrigeration
Universities/college	0.0	0.0	20.5
Library/Museum/Gallery	7.6	0.0	5.8
Total	**175.4**	**367.4**	**640.7**

Using Origami knowledge and expertise of smaller customers and third-party information sources allowed for the potential flexibility for typical assets at hotels, coffee shops and retail units to be identified. These assumed values are presented in Table *8* and Table 9 will be applied to businesses without any information regarding their energy use.

Table 9 - Assumed potential available flexibility for a common set of assets and business types

Customer	Business Type	Asset type	Estimated available flexibility in FUSION area by customer type (kW)			
			Available in Winter	Useful in Winter	Available in Summer	Useful in Summer
Hotel (large)	Accommodation	Space cooling and heating	208	182	104[20]	90
Hotel (Medium)	Accommodation	Space cooling and heating	69	60	35	30
Hotel (Small)	Accommodation	Space cooling and heating	5	0	0	0
Coffee shop	Catering	Air conditioning	3	1.5	2	1
Retail Unit (Small)	Retail	Heat barrier over door	2	0	2	0
Retail Unit (Small)	Retail	Air conditioning	3	2	3	2

With support from SP Energy Networks and direct engagement with several customers, half-hourly demand data was sourced for 29 sites across seven organisations. The Origami FlexFinder tool was utilised to analyse the variation in the demand profiles and estimate potential flexibility together with potential service revenue from TRIAD and DUoS avoidance. A summary of the analysis is presented in Table *10* and this indicates savings range from £35 to £3,920 from just two non-DSO services, depending on the level of flexibility available and assuming the asset can deliver the requirements of the service throughout the delivery period.

[20] Assuming 60-70% rooms occupied.

Table 10 - Summary of the flexibility identified from analysis of the half-hourly demand profiles.

Category	Estimated Potential Flexibility	Estimated saving per annum
Leisure Centre	S (10 - 20 kW)	£400 to £900
Education	L (65 kW)	£450 to £1,370
Government (offices)	XS (1-2 kW)	£35
Education	S (~11 kW)	£100 to £225
Government (Town Hall)	S (10 - 19 kW)	£320 to £660
Utilities	S (23-25kW)	£700
Education	XL (140)	£3,920

A review of public databases[21] and engagement with the business has provided information on the generation assets existing in the FUSION study area. A summary of which for industrial, commercial and SME customers is presented in Table *11*.

Table 11 - Aggregated existing generation presented at non-domestic and non-farming customers

Generation Type	Capacity (kW)
CHP	1,060
Onshore wind	13,500
PV	192
Standby diesel	1,100
Total	**15,852**

5.2 Farming Sector

The desktop study identified a wide range of agricultural activities which are carried out across the study area with a significant electricity demand and the potential to provide flexibility. These are listed in Table 12 together with the associated enterprise types. These values can be used as a proxy to identify relevant farming sectors and corresponding assets for further investigation.

[21] https://openinframap.org/, https://www.mygridgb.co.uk/map/, https://www.ref.org.uk/, https://www.carbonbrief.org/mapped-how-the-uk-generates-its-electricity

Table 12 - Mapping of enterprise types and assets present.

	Potato	Fruit & Vegetable	Cereals	Intensive livestock	Cattle / Sheep	Other (Incl. farm diversification)
Refrigerated crop storage	X	X				
Ambient crop storage	X		X			
Crop drying			X			
Crop grading/processing		X	X			
Irrigation	X	X				
Mechanical ventilation				X		
Feed preparation				X	X	
Space heating						X

Agricultural lighting demands are not considered suitable for flexibility in terms of the safety and welfare of staff and livestock and have been excluded. Cattle and sheep enterprises were initially included in the knowledge that some on-farm feed processing was carried out on these enterprises. However, during the telephone and email survey the current use of electrically powered feed mills was found to be insignificant within the East Fife area and therefore this enterprise type was not specifically targeted at the detailed study phase. On-farm generation in the form of renewable installations or alternatively standby diesel generators were identified.

In order to select representative consumers for the more detailed study stage the previously shortlisted 52 farms were reviewed in respect of their involvement in the remaining enterprise types. Only those farms with a significant involvement in at least one of the identified enterprise types or with on-site generation were considered suitable candidates for detailed study. From this list of suitable candidates, the final selection was made to ensure that all of the relevant activities were covered and following confirmation that the selected farmers were willing to participate in the study.

5.3 Domestic Sector

Table 13 summarises the data obtained from the following sources/activities for assets in East Fife:

- the desktop study;
- an information request issued to Ofgem seeking information on the number of installations in receipt of the Renewable Heat Incentive in the East Fife area;
- information obtained at the stakeholder engagement event to provide additional qualitative feedback regarding renewable installations across the East Fife area; and
- additional stakeholder engagement activity with; Fife Council, the University of St Andrews and the St Andrews Environmental Network as the major owners of property or intermediaries with property in the East Fife area.

Table 13 - Summary of domestic renewable energy installations in the FUSION study area

Renewable Energy Technology	Installed Capacity	Number of Installations	Total Capacity
Solar PV	4 kW	556	2,224 kW
Air Source Heat Pump	10 kW	22	220 kW
Solar Thermal	Data not available	9	Excluded
Ground Source Heat Pump	12 kW	7	84 kW
Electric Vehicle Charge Point	7 kW	3	21 kW
Total Capacity identified			**2,549 kW (including PV)** **325 kW (excluding PV)**

6 Site evaluation of flexibility

Visits to a selected number of representative customers sites were conducted to gather information about the site, the operating regimes (seasonal, day of week and time of day) and the flexibility capacity.

6.1 Industrial, commercial and SME sectors

The site evaluation of flexibility complements the desktop analysis, gathering information about the site, the operating regimes (seasonal, day of week and time of day) and the flexibility capacity. Three types of sites were evaluated;

- sites where half-hourly demand profiles were analysed using the FlexFinder tool - the site survey validated the identified flexibility and assessed constraints that could affect the use of the identified flexibility;
- sites of unique customers - determine the level of flexibility available; and
- smaller sites representative of sites within the FUSION study area - verify the assumptions in Table 10.

In all sites, existing flexibility has been estimated using the nominal power ratings of individual assets and from the maximum demand measurements on any dedicated circuits, e.g. off-peak heating.

- Some elements of the identified existing flexibility will not be accessible due to potential barriers identified below, although the level of incentive could have a significant influence, so this flexibility has been included in Table 14:
- Customer experience, e.g. poor previous experience or lack of understanding;
- Cost of enablement (technological and personal), e.g. smaller assets are more expensive to enable on a per kW basis;
- Landlord's permission to reconfigure equipment and controls; and
- Changes to operating procedures or flexible assets are fundamental to the business, e.g. hairdryers at a hairdresser.

Table 14 - Summary of the useful flexibility from estimated from the site visits

Site	A	B	C	D	E	Total
Flexible Assets	Pool heater Fan heaters[22]	None	GSHP CHP	Irrigation pumps; Heating pumps	EV chargers[23] CHP Air handling units[24] Electric heating[19] Ultra-cold freezers	

[22] Available flexibility would depend on the season and time of day flexibility is required; fans are generally operated on a timer.

[23] Assuming only half of the chargers are used simultaneously

[24] Total value of flexibility is not available until summer 2020 when an advanced building management and information system is implemented.

Useful Flexibility	96kW	0kW	78kW	8.5kW	>308kW	>485.5 kW

6.2 Farming Sector

The assessment of selected farm premises provided information on assets, operational parameters and existing generation is summarised in Table 15.

Table 15 - Findings from the assessment of the farms selected for the detailed study.

Type of Flexibility	Number of Premises	Capacity of premises
Cold Stores	3	▪ 1@700 tonnes; 1@1,500 tonnes; 2@2,000 tonnes
Grain Drier	7	▪ 4@1,000 tonnes / annum; 3@1,500 tonnes / annum
Intensive livestock (poultry)	2	▪ 1@3,000 birds; 1@9,000birds
Fruit & Vegetables	1	▪ 1@77 hectares
Other identified demands	2	▪ 1@bakery and planned renewables; 1@holiday let and leisure facilities
Standby generator	3	▪ 1@25kW; 1@65kW; 1@70kW
Solar PV	1	▪ 1@50kWp
Wind	2	▪ 1@22kW; 1@500kW

Following the site assessment, assets attributed to the farming business type were evaluated for the potential to provide flexibility based on the needs of the farm, key types of demand and generation. Summary of the identified potential for flexibility is presented in Table 16.

Table 16 - Potential to provide flexibility

	Potato	Fruit & Veg	Cereals	Intensive livestock	Cattle/ Sheep	Other (Farm Diversification)	On-site generation
Refrigerated crop storage	Yes	Note 1					
Ambient crop storage	No		No				
Crop drying			No				
Crop grading/ processing		No	No				
Irrigation	Note 2	Note 2					
Mechanical ventilation				Note 3			Yes
Feed preparation				Note 2	Note 2		
Space heating						Note 2	

Note 1 – none confirmed in FUSION study area
Note 2 – none identified in FUSION study area
Note 3 - these sites have standby generation to maintain ventilation which could be used to provide flexibility

6.3 Domestic Sector

Stakeholder engagement meetings took place with Fife Council, the University of St Andrews and the St Andrews Environmental Network to determine whether there were groups of domestic buildings (e.g. a social housing development or university accommodation block) which could be used to provide useful flexibility. From these meetings it was determined that unfortunately such groupings were not available due to negligible numbers of potential buildings within those groupings and that site visits should be targeted towards individual customers. For the domestic customers therefore, the site visits consisted mainly of interviews with a selected representative sample of residents across the East Fife area. The interviews took place at the University of St Andrews and in customer's homes. A data capture exercise was carried out relating to the sizing and status of existing renewable installations, the current energy tariff, mode of transportation e.g. Electric Vehicle (EV) or Internal Combustion Engine (ICE) vehicle. etc. The interviewees were highly engaged and informed about the energy system and where possible had invested time and effort in reducing their consumption of electricity at peak times. For example, one couple interviewed were on an Electric Vehicle Tariff which rewarded them for charging their EV overnight. Another interviewee carried out their clothes washing in the early morning rather than during the evening peak period. Electricity conserving behaviours also extended to the installation of insulation and smart meters where these meters were available.

An article on FUSION in the University of St Andrews Staff newsletter generated interest and attracted staff members willing to learn about the project and take part in interviews. Some of the interviewees have low carbon renewable installations in situ and a number who are considering installing low carbon renewable installations in the future. The installation of renewables was prompted by the availability of financial incentive schemes such as Feed in Tariffs and the Renewable Heat Incentive. Interviewees were highly motivated to take action to reduce the carbon impact of their households and were keen to learn about the potential role digital technology and renewable energy sources could play in supporting the decarbonisation agenda. The lack of access to finance to cover the cost of electricity or heat storage assets prevented interviewees from progressing with the purchase of such assets. The missing enabler for co-located energy storage results in these active households being classified as non-dispatchable for FUSION.

The hamlet of Radernie which is off the gas grid, has a cluster of customers who have installed a range of renewable technologies in their properties. These customers expressed support to participate in the FUSION trial and it may be possible, with the appropriate mix of enabling technologies, to create a low carbon hub across the hamlet. Customers in this area are interested in the options available to them to reduce their use of high-carbon heating sources e.g. oil or LPG. The motivation underpinning this is a combination of financial and environmental. Interviews identified a self-employed and highly-engaged renewable energy consultant with a solar array and EV charging point at home and access to real-time data who expressed an interest in participating in the trials individually and also to act as a coordinator for the local community.

There are low volumes of identifiable usable flexibility from the customers interviewed, driven by the lack of incentives for householders who have installed solar PV to also install electric battery storage systems. Without a despatch capability the solar PV in the East Fife area cannot be deployed as a flexibility asset for the purposes of the FUSION trial. The EV charging points installed at domestic premises are "dumb" i.e. they do not have the capability to be switched off or on remotely or for a reduction in demand. This lack of smart capability prevents the EV charging points and associated EVs from being considered for FUSION trials. The Department for Transport is currently consulting on new requirements under the Automated and Electric Vehicles Act 2018, requiring all non-public EV charge points to be smart which will hopefully remove this barrier going forward. Innovations in smart EV charging and EV tariffs which reward customers for charging their EV's overnight or outside of peak time periods are expected to motivate domestic consumers to move towards controllable assets which can then be used in demand response markets. For example, Scottish Power have recently launched a Smart EV Charger[25] and a SmartPower EV tariff which will enable customers to benefit from a cheaper electricity tariff when charging their electric vehicles.

[25] https://quote.scottishpower.co.uk/electric-vehicles

7 Growth potential during FUSION project

Project FUSION is scheduled to be active until 2023, running multiple trials to test a USEF-compliant flexibility market under a range of scenarios. The following sections provide the overview of anticipated changes in demand and generation per sector in the lifetime of the project.

7.1 Demand

7.1.1 Industrial, commercial and SME sectors

Table 17 - Possible demand growth from Industrial, commercial and SME sectors

Customer	Opportunity	Potential Flexibility	Timescale
Site A Education	The site is relocating over the next two years and flexibility could be integrated into the design.	Uncertain and will be subject to discussions with customer.	2 years
Site D Leisure	The current heating infrastructure is very old and will be upgraded to a CHP and heat pumps.	Uncertain at this stage as gas could be used but may involve “heating as a service”.	2-3 years
Site E Education	Staff to be relocated, along with several departments, Inc incubators and chemistry labs which will increase local demand by 250kW	Potential for heating and ventilation flexibility to be determined; there will be 10 individual 7kW EV chargers.	Within 1 year
Brewery and distillery	The brewery will relocate to a new temporary site while a permanent site is built. They are interested in discussing the integration of flexibility into the new site.	Uncertain at this stage but there is the potential for heat pumps and CHP.	2-3 years

7.1.2 Farming Sector

Changes in energy demand to 2025 from the farming sector are likely to come from two factors:

- Releasing existing network capacity constraints as a result of the relatively high cost of infrastructure development (new connection requirements and / or increasing existing connections, e.g. three premises were identified where 190kW of demand is currently delivered from off-grid generation) that will increase demand and / or increase distributed generation.
- Changes to farming practices, particularly those associated with the increase in EVs and the conversion of farm vehicles to electric will increase underlying demand.

7.1.3 Domestic Sector

There are three new housing developments in the East Fife area that should be completed prior to major FUSION trials commencing that will result in ~1,300 new homes. St Andrews West is a mixed use development of ~900 new homes with c30% of the homes being allocated to affordable housing. Two developments in the Guardbridge area will result in 395 homes with 160 allocated to affordable housing. Given the existing rate of growth, further developments should be expected.

Additional flexibility could be achieved by pairing energy storage devices with existing PV installations and installing smart controls. The addition of a 2kW electric battery storage system together with smart controls to a 4kW Solar PV installation could provide 1kW of peak load reduction. Extrapolating this approach to the 556 4kW solar PV installations in the East Fife area would equate to the creation of c.0.5MW of peak demand flexibility.

From a retrofit perspective, customers who use oil or LPG as their heating source are potential candidates for adopting hybrid Air Source Heat Pumps which can deliver an 80% carbon reduction and significant cost savings.

Installing more clusters of LCTs such as heat pumps could require the reinforcement of an LV feeder depending on the volumes deployed. The typical cost of reinforcing an LV feeder is £40,000 - £100,000, based on ground mounted substation and cable upgrades, as published by WPD in their East Midlands QAS (part of the Connection Charging Methodology). Where smart controls are installed and predictive load control services enabled, this reinforcement cost can be mitigated, and additional flexibility created. Should this model be adopted at scale across the East Fife area, the increased demand on the local network could be used as a flexibility resource in future flexibility markets

7.2 Generation

7.2.1 Industrial, commercial and SME sectors

Table 18 - Potential developments of generation on Industrial, commercial and SME sector sites.

Customer	Plans	Timescale
Site D Leisure	CHP; possibility to deliver "heat as a service" but could use gas to provide heat directly as there is a good gas connection.	2-3 years
Site C Healthcare	Flexibility may be provided by energy storage or gas-based generation; possibility to deliver “reliability as a service”	4-5 years
Site E Education	Flexibility may be provided by energy storage or gas-based generation; possibility to deliver “reliability as a service”	3-4 years
Site E Education	1.2MW PV peak (1.0MW certain, additional 0.2MW subject to sufficient roof strength); largely unsuitable for demand turndown unless co-located with storage (there is space for storage to be located)	Within 12 months
Site E Education	0.7MW CHP (500kW and 200kW – this one will be used as primary source for heating); 500kW suitable for flexibility services.	Within 6 months

Customer	Plans	Timescale
Brewery and distillery	The brewery will relocate to a new temporary site while a permanent site is built. They are interested in discussing the integration of flexibility into the new site which could include heat pumps and / or CHP.	2-3 years

7.2.2 Farming Sector

No additional generation is expected to be installed in the timescale of FUSION although several premises have the potential for a generation project, but the existing electricity connection is too small or does not exist. Three premises were identified where 190kW of demand currently delivered from off-grid generation could be replaced through a network connection.

7.2.3 Domestic Sector

Housing developers are currently not incentivised to enable renewable smart energy system optimisation and without an external influence it is unlikely that the new homes being planned will be designed to incorporate embedded generation. and to provide flexibility services. The Scottish Government historically has prioritised improving the energy efficiency elements of housing standards in order to reduce the number of households in fuel poverty and to reduce the contribution housing makes to climate change. More recently following the publication of the Committee on Climate Change Net Zero Report has led to the Scottish Government implementing legally binding commitments to achieve Net Zero by 2045. In order to achieve this target, changes to building regulations including the proposed ban on fossil fuel boiler installations from 2024 are intended to motivate housing developers to alter their designs to include renewable technologies

The planning permission proposal for Guardbridge Village is currently under review by Fife Council, and if it is approved then it will be important to seek engagement with the developers to ascertain whether the plans currently include renewable energy installations.

8 Summary of available flexibility

Desktop evaluations and site surveys of the customers in the FUSION study area quantified flexibility over a range of assets, locations and seasons and this section summarises the flexibility evaluation by geographical distribution

Except for the large individual sites such as hospitals, large hotels and university buildings, most of the flexibility is located at the low-voltage level. Larger customers or single building load centres are connected to the 11kV network. When considering flexibility by substations, the pivot is the bridge at Guardbridge: north-west from the bridge is supplied from Leuchars primary substation whilst areas east from the bridge are supplied from the St. Andrews primary substation.

8.1 Geographical distribution of flexibility

The geographic distribution of flexibility for the non-domestic and non-agricultural sectors are illustrated in Figure *10* and Figure *11* and farming customers in Figure 12. In order to protect customers identification, the flexibility areas are aggregated up-to 6-digit of the post code, e.g. KY16 8Q, instead of KY16 8QD. Because of the allocation of the post codes in the area, some of the post codes with high flexibility are marked to be in a rural area.

8.2 Flexibility Matrix

Based in the combined findings from sector specific report, summary of the available flexibility per sector and per asset is presented in this section in two formats: a detailed table and graphical representation.

8.2.1 Available flexibility across sectors

A detailed summary of the estimated available flexibility across the I&C and SME sector, agricultural sector and domestic sector is presented in Table *19*. The values in the table represent the aggregated available nominal[26] flexibility per SIC sector and per asset type.

[26] Nominal in terms of asset rating and being available at a point in a day (i.e. not considering business specific usage during business hours).

Table 19 -Estimated available flexibility per sector and asset type per season and day of the week.

SIC sector	Asset type	Estimated available flexibility (kW)			
		Winter		Summer	
		Weekday	Weekend	Weekday	Weekend
Farming	Standby generators	185	185	185	185
	Refrigeration (potato store)	19	19	33	33
Domestic	Air Source Heat Pump	220	220	0	0
	Ground Source Heat Pump	84	84	0	0
	EV charging	21	21	21	21
	Time of-Use response	10% of peak demand			
Professional, scientific & technical	Heating	90	0	0	0
	Air conditioning	0	0	45	0
Retail	Heating	186	186	0	0
	Air conditioning	0	0	54	54
	Chillers	87	87	87	87
Accommodation & food services	Heating	117	117	0	0
	Air conditioning	183	183	642	642
	Chillers	299	299	125	125
Arts, entertainment, recreation & other services	Heating	89	89	0	0
	Air conditioning	0	0	45	45
	Chillers	348	348	348	348
	Pumps	9	9	9	9
Business administration & support services	Heating	74	26	0	0
	Air conditioning	0	0	17	1
	Chillers	9	9	9	9
Production	Pumps	23	23	23	23
Health	Heating	99	78	78	78
	Air conditioning	0	0	7	0
Motor trades	Heating	11	0	0	0
	Air conditioning	0	0	4	0
Transport & Storage (inc. postal)	Heating	2	2	0	0
Education	Heating	99	99	36	36
	Chillers	21	21	21	21
	Generation	238	238	238	238
	EV charger	50	0	50	0
Public administration & defence	Heating	2	2	0	0
	Air conditioning	0	0	2	2
Total Flexibility (kW)		**2,562**	**2,342**	**2078**	**1,956**

8.2.2 Flexibility Bubble chart

High level overview of the available flexibility per sector, asset type and voltage level are illustrated in *Figure 9*.

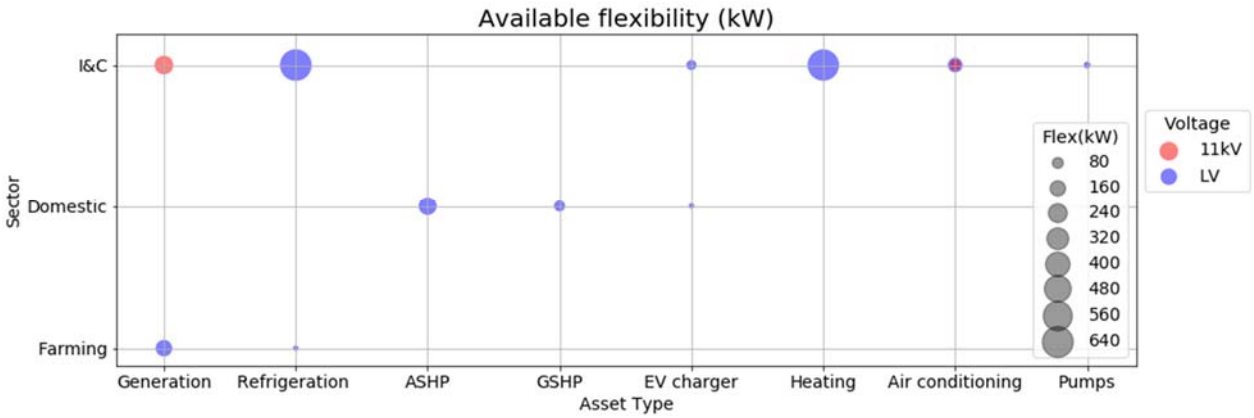

Figure 9 – Distribution of available flexibility by sector and by asset type

8.2.3 Location of Flexibility

The flexibility available within the East Fife area is summarised in Figures 10 to 12.

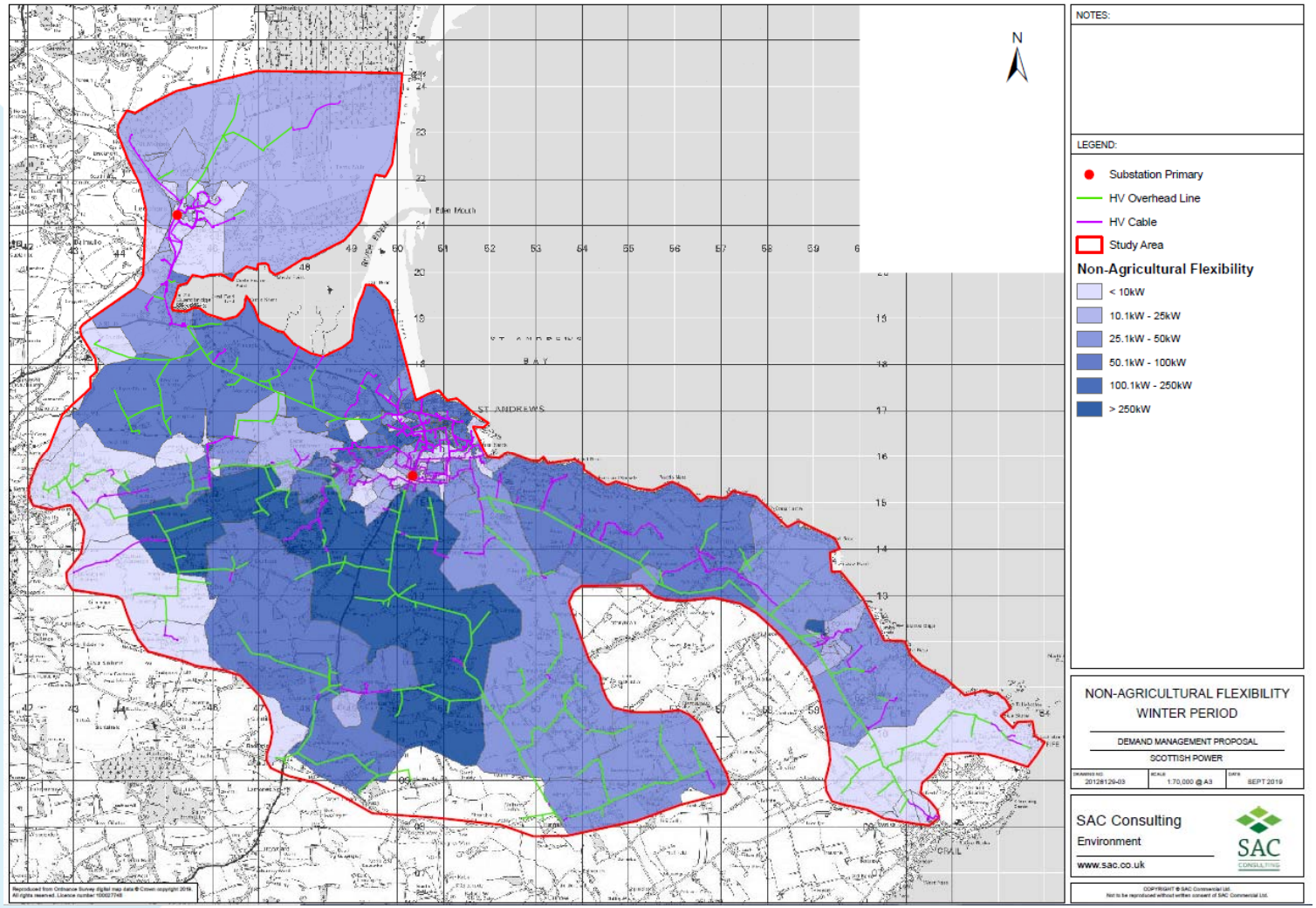

Figure 10 - Mapping of the available flexibility in Winter months attributed to non-domestic and non-farming customers. Flexibility polygons are based on the first 6 digits of the customer postcode.

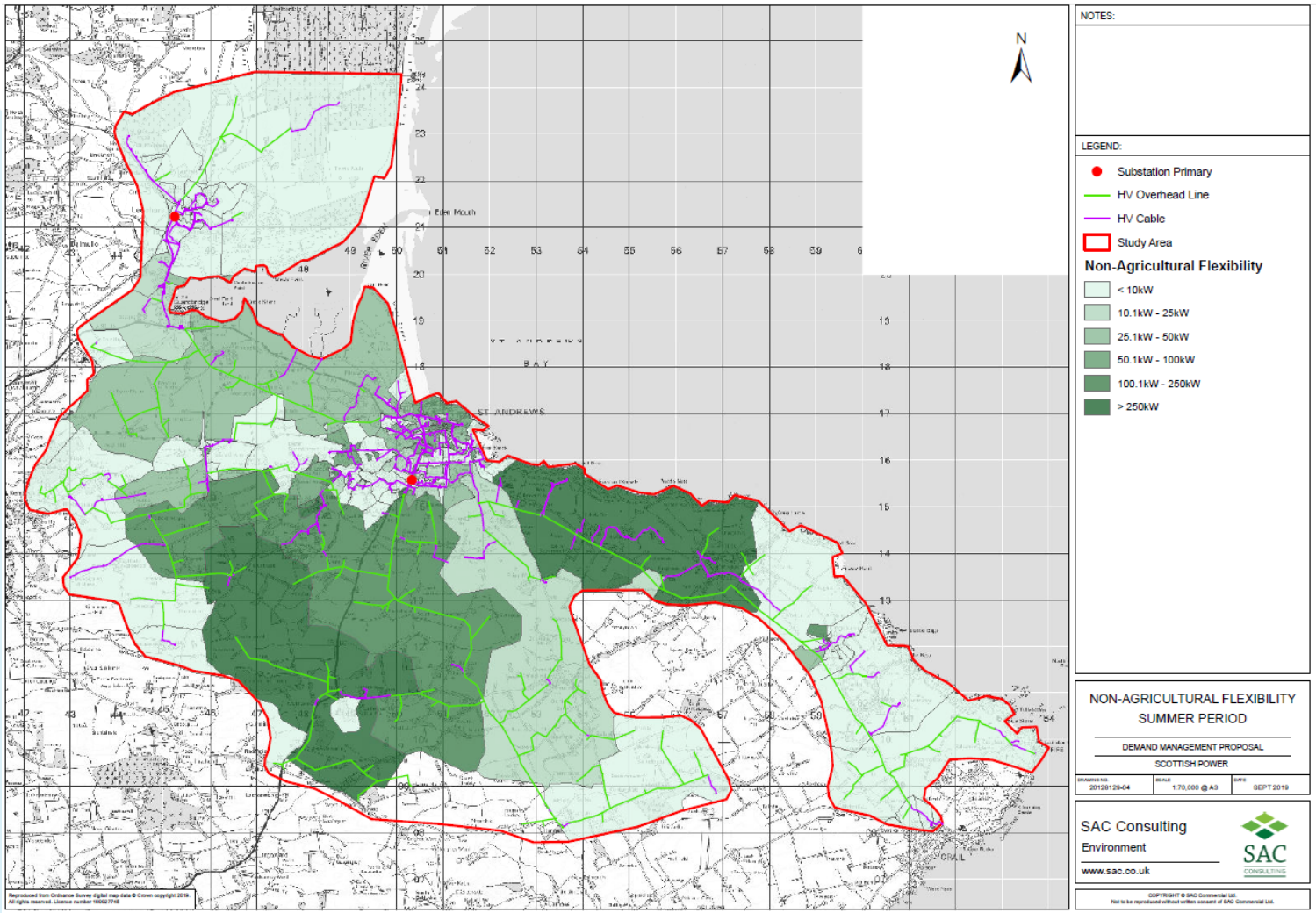

Figure 11 - Mapping of the available flexibility in Summer months attributed to non-domestic and non-farming customers. Flexibility polygons are based on the first 6 digits of the customer postcode.

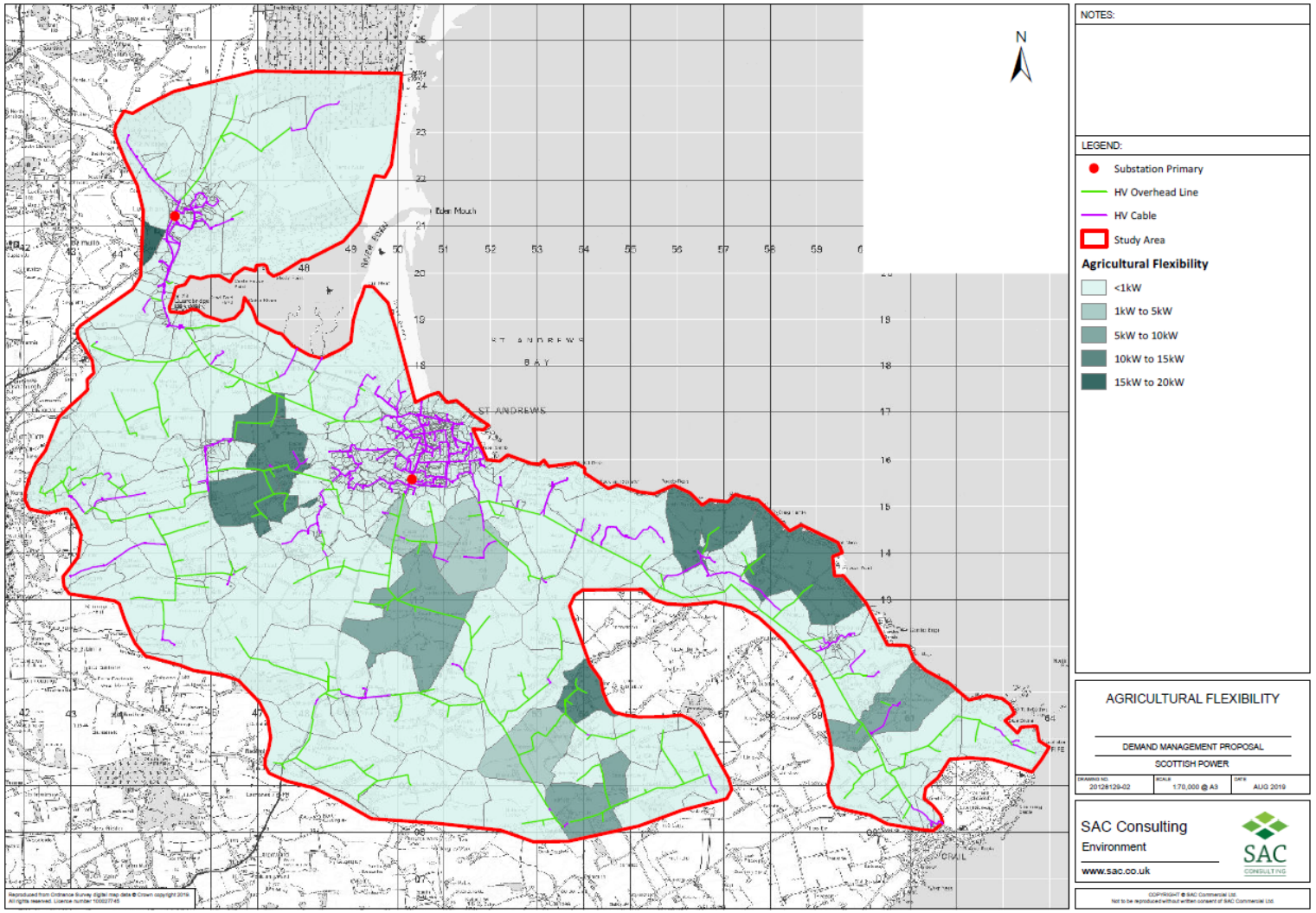

Figure 12 - Mapping of the available flexibility attributed to farming customers. Flexibility polygons are based on the first 6 digits of the customer postcode.

9 The economics of enabling flexibility

This section discusses the Origami approach to enabling flexibility to provide commercial flexibility services. This approach is applicable across sectors but enabling flexibility in the domestic sector is a special case and Is discussed in section 9.4.

9.1 Enablement Process

Enabling an item of flexibility has four steps as illustrated in Figure *13* and expanded in Table 20. The key concern Is to ensure that the use of the item of flexibility has no detrimental effect on the normal operation of the business and within parameters agreed by the owner / operator of the Item of flexibility.

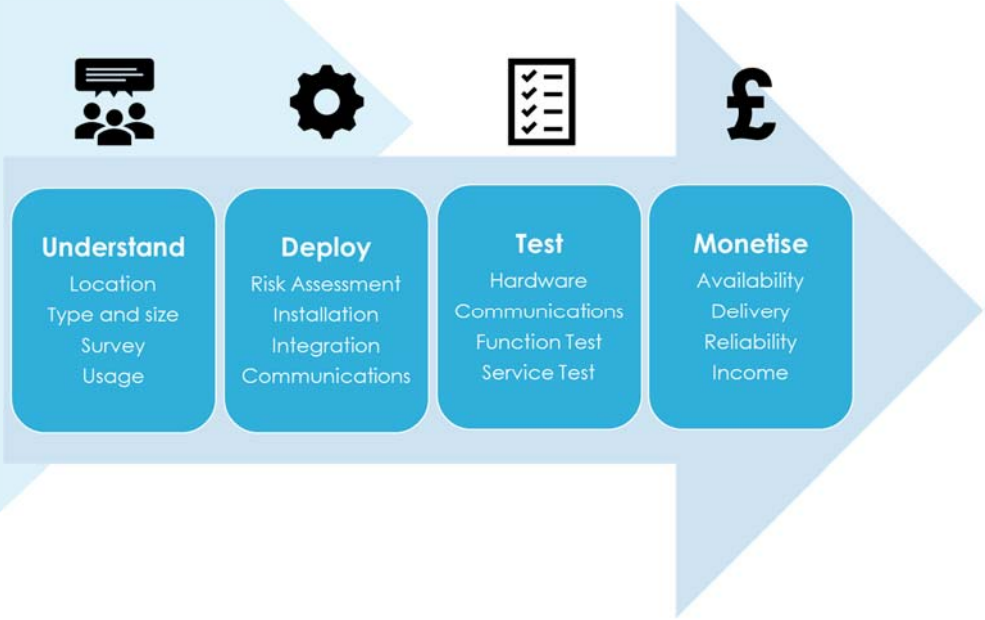

Figure 13- Illustration of enablement steps

Table 20 - Summary of enablement steps

Step	Summary of key
Understand	▪ Location - determines the flexibility services that can be delivered by the item of flexibility (local, regional, and national). ▪ Type and Size - determines the cost effectiveness of the enablement and the potential services that could be delivered by the item of flexibility. ▪ Survey - verifies the parameters of the item of flexibility and determine the likely flexibility services that could be delivered. ▪ Usage - determines how often the item of flexibility could be utilised within a given time period, set by the owner or operator.

Step	Summary of key
Deploy	▪ Risk Assessment - consideration of the risk of installing and connecting the hardware to ensure a safe installation and the potential for damage to property during the installation process. ▪ Installation - the installation of the hardware on site (not always required) ▪ Integration - the integration of the hardware with the item of flexibility (usually the management system of the item of flexibility). ▪ Communications - determines the optimum communication solution (usually an internet connection).
Test	▪ Hardware - ensure it operates as expected. ▪ Communications - ensure the communications route is reliable and secure and determine a backup route for large items of flexibility. ▪ Function Test - ensure the hardware communicates with the platform as expected. ▪ Service Test - run specific flexibility service tests to ensure the item of flexibility is capable of delivering the flexibility service and the measurement system works.
Monetise	▪ Availability - the ability to change when the item of flexibility can be used to deliver flexibility services; the more an item of flexibility is available to deliver flexibility services, the higher the revenue. ▪ Delivery - on-time delivery of flexibility services in accordance with agreed parameters will maximise revenue. ▪ Reliability - delivering flexibility services on time, at the rate agreed, and for the duration agreed will maximise the revenue generated. ▪ Income - enjoy the revenue from the use of the item of flexibility to deliver flexibility services.

9.2 Cost effective enablement

Cost effective enablement requires a low enablement cost per unit of flexibility. When the level of flexibility is high, this is a relatively obvious and intuitive calculation, but may not be the case at lower levels of flexibility as illustrated in Table 21.

Each item of flexibility enabled also has an opportunity cost for developing the relationship and for negotiating and managing the agreement and this Is lower for customer with a portfolio of large items of flexibility compared to one with a large of number of customers each with a small number of items of flexibility each with a small level of flexibility. The issue is not the relative capacity of an item of flexibility but the relative capacity of all items of flexibility that can be enabled for the sum of the opportunity cost and the cost of enablement.

Table 21 - Economics of enabling flexibility

Level of flexibility (in kW)	Number of items of flexibility	Annual Revenue from flexibility services from flexibility	Cost of enablement[27]	Net revenue from flexibility services (£/kW/year)	Enablement payback (years)
1,000	1	£89,000	£5,000	£84	0.06
500	1	£44,500	£5,000	£79	0.11
250	1	£22,250	£5,000	£69	0.22
100	1	£8,900	£5,000	£39	0.56
50	30	£133,500	£25,000	£72	0.19
50	1	£4,450	£5,000	-£11	1.12

In today's flexibility marketplace, few aggregators and suppliers who aggregate flexibility have a proposition for smaller assets that is cost effective.

9.3 Revenue maximisation

The value for any flexibility service will be reduced based on the following factors;

- The level of over-procurement by the flexibility service beneficiary - a higher level of over-procurement will reduce the relative income;
- The route to market - the more parties in the flexibility delivery chain, the lower the value;
- The level of overprovisioning - a higher level of overprovisioning will reduce the relative income;
- The level of availability - the more an item of flexibility is available, the higher the flexibility services revenue, particularly over tea-time peak; and
- The reliability of the item of flexibility - the higher the reliability, the more the item of flexibility is likely to be used and the higher the revenue from flexibility services.

9.4 Domestic flexibility

With regard to the domestic customer market, the enablement process is at an earlier stage of maturity than the commercial market. The financial return that can be delivered to each domestic consumer is correspondingly small, so the incentive to participate is small in comparison to the financial reward non-domestic customers can expect. For example, domestic customers who take part in MOIXA's GridShare Platform receive an annual payment of £50 for allowing access to the new installations of a MOIXA smart electric storage battery installed in combination with Solar PV

[27] assumes a fixed one-off cost to enable an asset (except small assets which are enabled by software) and that all assets can deliver the same services

systems. This is in contrast to a non-domestic customer providing flexibility services to a Distribution Network Operator such as Western Power Distribution, who would be entitled to an annual payment of c£800 for making 0.25MW of flexibility available in a constraint managed zone (WPD FlexAssure Service).

For mass market products, major technical enablers e.g. smart controls, smart metering, half hourly settlement and modifications to the market mechanics such as proposed change P379 "Multiple Suppliers Through Meter Splitting" are yet to be fully implemented. There are financial barriers to the adoption of low carbon heating technologies such as Air Source Heat Pumps (ASHP) and electricity storage batteries by local authorities and individual domestic customers. The Renewable Heat Incentive has not driven a high take up of ASHP's which limits the volume of assets which can then be made available to aggregators. There are missing financial incentives to enable the co-location of Solar PV and Battery Storage. New financial and market mechanisms are required to drive up the volume of controllable low carbon domestic assets which can then be made available to flexibility markets. There are missing incentives and regulations to motivate housing developers to install low carbon controllable systems into new build developments which prevents domestic customers from accessing future value from flexibility. There is also a requirement to establish an appropriate customer protection framework to provide assurance that domestic demand response products will provide fair value. An issue which will need to be addressed is how to ensure customers in fuel poverty or vulnerable circumstances are not discriminated against or left behind. Once these mechanisms have been implemented on a mass market basis, it will be possible for domestic customers to participate in optimisation activities such as peer to peer trading as well as providing flexibility to DNO's/DSO's via demand response aggregators.

The domestic flexibility assessment work undertaken by PassivSystems through WP2 suggests that the available flexibility identified in the residential sector is insufficient to warrant its participation in the FUSION trials. The lack of flexibility in the residential sector in East Fife is thought to result from the consumer business case for adopting low carbon technologies (LCTs) which can be despatched and made available still being uneconomic for most households in the East Fife area. PassivSystems therefore recommends that the FUSION Project considers either;

- stimulating the uptake of flexible domestic LCTs,
- excluding domestic sites from the trial, or
- agreeing the despatch from domestic flexibility outside the East Fife area.

10 Services over time and the potential value of flexibility

Traditionally the ESO was the only buyer of flexibility services from embedded flexibility and this monopsonistic[28] position provided them with significant market power. However, the ESO has successfully increased competition through reducing the barriers entry and this has reduced the cost of flexibility services. This has stalled the construction of new flexibility capacity as the value of flexibility services, even when stacked, is insufficient to make projects economic. The consequence is an increased interest in embedded flexibility which does not require the same level of investment to enable. In December 2018, the six GB DNOs formally entered the flexibility marketplace with the Flexibility Commitment[29]. The Flexibility Commitment clearly states that DNOs will "*Openly test the market to compare relevant reinforcement and market flexibility solutions …*" and *"… to develop the forthcoming RIIO-2 price control framework to ensure that the financial incentives that network companies receive are fully aligned with the greater use of flexibility services and do not favour the building of new infrastructure where these services are more efficient*." UKPN announced[30] in early July 2019 that 18.1MW has been procured as a commercial service, a milestone in the flexibility marketplace. It creates a duopoly now with other DNOs looking to enter the marketplace through the procurement of flexibility as a commercial service, e.g. SP Energy Networks have recently tendered for flexibility[31].

10.1 Uses of Flexibility

There are a number of general use cases for flexibility, all of which depend on the parameters of the flexibility and the requirements of the flexibility service; this is illustrated in Table 22.

Table 22 - The Uses of flexibility by Different Market Actors

Market Actor	Immediate	Short-Term	Long-Term
Electricity System Operator	▪ Balancing Mechanism	▪ Ancillary Services ▪ Trading in markets	▪ N/A
Distribution Network Operator	▪ Constraint Management	▪ Peak Management	▪ Defer or avoid capital expenditure
Supplier	▪ Imbalance Management ▪ Balancing Mechanism	▪ Portfolio Management ▪ Trading opportunities	▪ Portfolio Management ▪ Trading opportunities
Aggregator	▪ Ancillary Service ▪ Wholesale trading ▪ Imbalance management	▪ Ancillary Service delivery ▪ Ancillary Service auctions	▪ Constraint Management
Flexibility Provider	▪ Flexibility delivery to other market actors	▪ Ancillary Services	▪ Constraint Management

[28] Meaning a single buyer from multiple supplies as opposed to monopoly with single supplier and multiple buyers.

[29] http://www.energynetworks.org/assets/files/ENA%20Flex%20Committment.pdf

[30] https://www.current-news.co.uk/news/ukpn-piclo-herald-significant-milestone-as-winners-emerge-from-maiden-commercial-flexibility-tender

[31] https://www.spenergynetworks.co.uk/news/pages/sp_energy_networks_opens_its_largest_tender_for_flexibility_services.aspx

Market Actor	Immediate	Short-Term	Long-Term
Consumers	▪ Capacity and Energy Management ▪ Cost reduction	▪ Profile Management	▪ N/A

The relative timescales for the range of flexibility services available to new providers of flexibility is illustrated in Figure *14*. This ignores wholesale trading as a service as the timescales vary depending on the agreement with the trading counterparty.

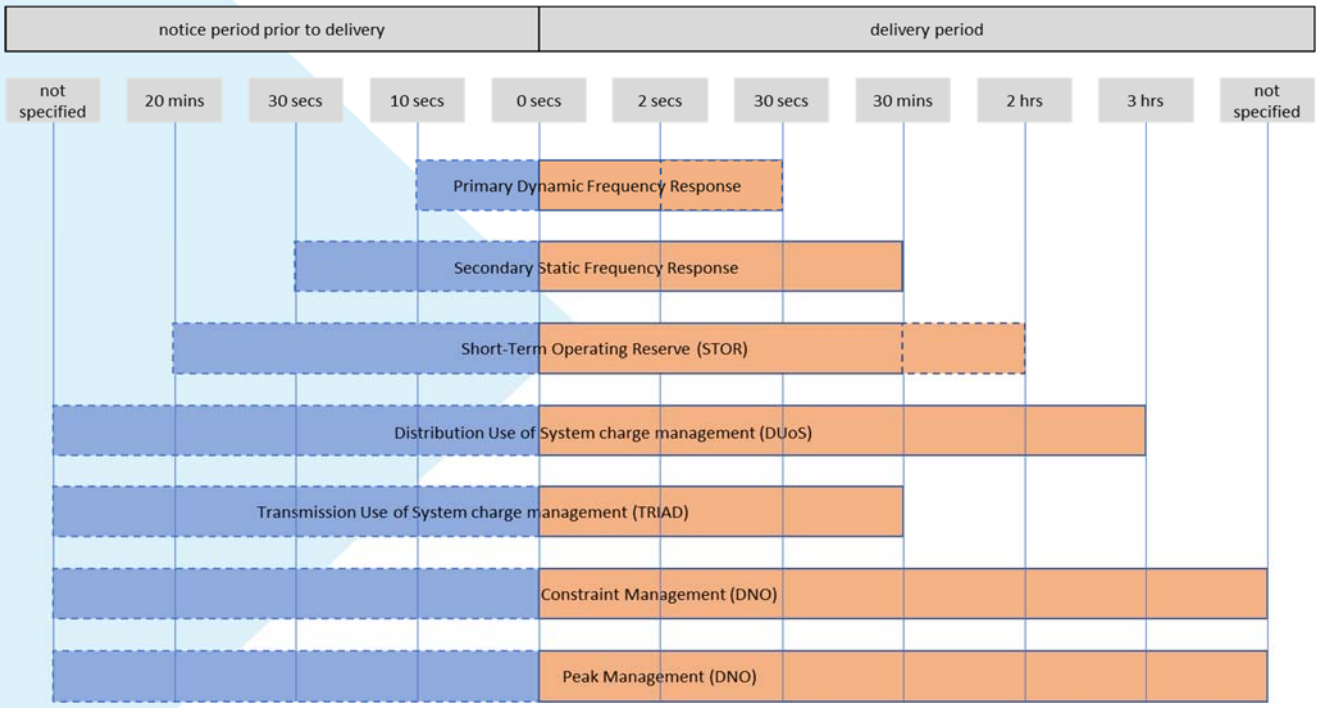

Figure 14 - Relative timescales for flexibility services available to new providers of flexibility

10.2 Value of Flexibility

The reduced barriers to entry to participate in the provision of Ancillary Services to the ESO, and the resulting increased competition, has had the effect of reducing market prices. This is illustrated in **Error! Reference source not found.**[32] with the average price in Nov-18 (~£24/hour) more than 55% less than the average price in Feb-17 (~£54/hour).

At the Power Responsive 2019 summer reception in June 2019, Baringa presented analysis that highlighted the state of the flexibility marketplace;

- between 2015 to 2019, the value of ancillary services had reduced by 81% for fast reserve, 61% for firm frequency response, and 20% for committed STOR, although flexible STOR had increased by 11% over the same period; and

[32] Chart 15: FFR – Accepted prices for static FFR from January 2017 – December 2018 Availability prices (£/h) accepted for static FFR across January 2017 – December 2018 (only DSF providers participated)

- if a 1MW "front of meter" battery located in east Midlands had been commissioned in 2017, it would now only receive 56% of the income level, less than an assumed project return of 10%.

The value for flexibility is sufficient to encourage a growth in existing assets providing flexibility services, subject to cost-effective enablement. The high relative cost of enablement for smaller assets means that some assets are currently uneconomic to enable. However, development of the enablement solutions for smaller assets is ongoing and likely to present greater opportunity to access this flexibility cost effectively in the near future. In addition, the value of flexibility is currently too low for new dedicated flexibility projects to achieve project returns and this is affecting the growth of flexibility.

A further issue for flexibility is that the whole of system benefit that could be attributed to flexibility includes benefits that are not accessible to all market actors. Further, each market actor values flexibility based on how it uses that flexibility with some market participants obtaining additional benefits as a consequence of purchasing flexibility to provide a single service with the additional benefits obtained at either a low cost or no cost[33].

The value of flexibility from non-DSO flexibility services (ranging from DUoS charge avoidance to frequency response services) was discussed by Origami at the FUSION Engagement Stakeholder held on 27 June 2019. This value is illustrated in Figure 15 and discussed in Table *23*. It was highlighted that flexibility with lower availability would receive lower revenues.

Figure 15 - Total income for flexibility services at May 2019 (excluding any revenue from SP Energy Networks).

[33] "Analysis of relevant international experience of DSO flexibility markets", published 28 August 2019, https://ssen-transition.com/library/

Table 23 – Revenue included in Figure 16 for non-DSO flexibility services

Flexibility Service	Some Flexibility	Specialist Flexibility	Fast Flexibility
Transmission Use of System charge management (TRIAD)	X		
Distribution Use of System charge management (DUoS)	X		
Capacity Market		X	X
Wholesale Trading		X	X
Imbalance Management		X	X
Short-Term Operating Reserve (STOR)			X
Frequency Response			X

The value of flexibility from SP Energy Networks is uncertain at the time of writing and is dependent on local factors, including; the speed of service delivery, the avoided cost, and the opportunity benefit. The flexibility prices offered by Western Power Distribution's Flexible Power project[34] (see Table *24*) provide an indication of prices offered for DSO flexibility services to encourage participation. In November 2019, the SP Energy Networks Durie House auction on the PicloFlex platform gives another example of price for flexibility in proximity to the FUSION study area of £75/MW/h for availability and £600/MWh for utilisation[35] (equivalent to £9.30/kW/year, excluding utilisation).

Table 24 - Flexibility Prices for Western Power Distribution's Flexible Power project

Flexibility Service	Arming	Availability	Utilisation
Secure	£125/MWh	N/A	£175/MWh
Dynamic	N/A	£5/MWh	£300/MWh
Restore	N/A	N/A	£600/MWh

In addition to the income from flexibility indicated in Figure 15, an additional revenue of £9/kW/year has been assumed for the value of DSO flexibility services in the East Fife area. However, there may be a premium for FUSION due to the additional operational burden of interacting with USEF.

10.3 Combined Effect of Over-procurement and Overprovisioning

The ENA Engineering Technical Reports 130 and 131 provides a methodology for assessing the security contribution from distributed generation (referred to as the "F-factor"). These F-factors were used in Low Carbon London to determine the

[34] https://www.flexiblepower.co.uk/faqs

[35] Durie House flexibility auction on PicloFlex, 15 November 2019, https://picloflex.com/dashboard?competition=eyKX9VN"

security contribution from various generators of a similar rating but did not consider the risk where the generators were of different and / or disproportionate ratings in a pool of generators[36]. Low Carbon London also defined a new set of "F-factors" for demand side response to provide DNOs with an indication of the amount of "over-procurement" likely to be required by the DNO to ensure the necessary response will be delivered[37].

Providers of flexibility get penalised if they fail to deliver on their contract obligations. As such, the flexibility provider will generally provide more flexibility than it has contracted to deliver to cover any shortfalls in delivery, "overprovisioning"

The combination of over-procurement and overprovisioning could result in a significant reduction in the flexibility being contracted but not used (up to 100% under many scenarios) and this issue should be considered in the structure, compensation, and penalties in any contract[38].

10.4 Factors Affecting the Value of Flexibility

The value from using flexibility depends on a number of different factors, including:

- Asset capability - the level of flexible capacity, the speed of response, the delivery duration and its availability;
- Services to be delivered - the ESO has the highest level of service requirements but competition has depressed the value of flexibility, DNO services are only just starting to be purchased on a commercial basis, additional services are available through the supplier (or, rarely, the aggregator) include wholesale trading, and the flexibility owner can use the flexibility for self-balancing. It is uncertain what effect the increased routes to market for flexibility will have on the value for flexibility services; and
- Ability to access the full value of services as different market participants can only access a limited proportion of the system value for flexibility, e.g. there is no means of some projects obtaining a revenue equivalent to the value that GB get as a result of the carbon benefits that accrue from using flexibility rather than a carbon-based flexibility.

Following on from the extrapolation of the available flexibility, the value of the flexibility for the DNO in the FUSION area will be driven by the reliability and the availability at the upper and lower error bounds of flexibility at the time when the constraints occur. Reliability of the available assets has a profound impact on the value of flexibility due to over-procurement and over-provision.

The value of flexibility for each customer is driven the operational parameters of the flexible asset and the services are accessible to the customer (directly or through aggregation). The simplest value can be achieved through performing arbitrage against the Triad and Distribution Use of System charges. However, the cost of enablement of flexibility to access these services could be prohibitive for customers with smaller assets.

[36] "Distributed Generation addressing security of supply and network reinforcement requirements", UK Power Networks, September 2014.

[37] "Industrial and Commercial Demand Response for outage management and as an alternative to network reinforcement", UK Power Networks, September 2014.

[38] "Task-4.5 Services in a Facilitated Market v3.0", published on 21 August 2019, https://ssen-transition.com/library/