Net Zero Terrace

Strategic Innovation Fund Project

Discovery Phase

Work Package 3: DNO/DSO Operation Interfaces

May 2023

Electricity North West

Version

Version	Date	Author	Status	Comments
V1	05/05/2023	Chris Greenfield	Complete	First Draft

Review

Name	Role	Date

Approval

Name	Role	Signature & date

Contents

Table of Figures

Table of Tables

Acronyms and Abbreviations

ADMD	After Diversity Maximum Demand
CEM	Common Evaluation Methodology
CNE	Combined-Neutral-Earth
COP	Code of Practice
DER	Distributed Energy Resource
DFES	Distribution Future Electricity Scenarios
DNO	Distribution Network Operator
DSO	Distribution System Operator
DUOS	Distribution Use Of System
ENA	Energy Networks Association
ER	Engineering Recommendation
ENWL	Electricity North West Limited
EPD	Electricity Policy Document
EREC	Engineering Recommendation
GIS	Geographical Information System
GSHP	Ground Source Heat Pump
KW	Kilowatts
LCT	Low Carbon Technologies
LV	Low Voltage
MAD	Minimum Average Demand
MDI	Maximum Demand Indication
NMS	Network Management System
PACE	Pre-Application Customer Engagement
PCM	Phase Change Material
PoC	Point of Connection
PPA	Power Purchase Agreements
PSCC	Prospective Short Circuit Current
PV	Photovoltaic
SCR	Significant Code Review

1 Introduction

This report outlines the scope for Work Package 3 in the Net Zero Terrace Strategic Innovation Fund (SIF) project. This is initial stage known as the discovery phase. As part of the Work Package, a first draft report on the DNO/DSO operation interfaces shall be submitted by 10/05/2023 and upon review shall be amended into a final report by 26/05/2023.

A meeting was held on the 20/04/2023 with one of the main project partners 'Buro Happold' to discuss the proposed design in more detail. An initial feasibility study was sent to Electricity North West Limited (ENWL) by Buro Happold which was carried out in Bacup to determine the most efficient and cost-effective ways in which to connect Low Carbon Technologies (LCT) together on a large scale via a community led Smart Local Energy System (SLES) to decarbonise terraced streets.

Terraced houses are a challenge to decarbonise when considering electrification of heat and transport due to space constraints, noise constraints and efficiency losses. This leads to customers in these homes being left behind during the energy transition and unable to participate in schemes to lower bills and reduce their carbon footprint.

The proposed SLES consists of:

- **An individual Ground Source Heat Pump (GSHP) at each property on a row of terraced houses which are all connected via a shared ambient loop (5th generation) heating system. A Kensa Shoebox 6kW GSHP is the proposed unit which is small, compact, quiet and suitable for terraced homes where space utilisation is necessary.**
- **A shared Solar Photovoltaic (PV) array laid across the roofs of the terrace row to generate clean energy during peak sun hours. This community owned energy can either be used to supply the homes at a discounted rate via a Power Purchase Agreement (PPA) or to export into the network via wholesale and flexibility markets. There are two connection options to be explored, a private wire behind the meter option and a direct connection into the Low Voltage (LV) network.**

The SLES will be up to four times more efficient than a counterfactual option of electric boilers, and thereby considerably reduces both network capacity requirements and consumer bills.

The interface requirements considered at this stage for the DNO/DSO include:

- **Point of Connection (PoC) into the network**
- **Reinforcement requirements**
- **Flexibility requirements and options**

This report details a feasible connection option into the ENWL network for the SLES and considers any policy requirements that need to be adhered to. The range of flexibility options is also explored. It is important to note that network capacity and flexibility requirements can change in time, therefore should an application be submitted for connection or flexibility at a later date, the details in this report may have expired.

2 Existing Network

The study area in Bacup consists of a main and an additional boundary shown in Figure 2-1 Main Boundary. The main boundary (yellow boundary) encompasses the rows of terraced street housing from Albert Terrace to Ash Street, Beta group industrial buildings, the Grade II listed historical water mill, and homes between Alder Street and Burnley Road.
The additional boundary (orange) includes the terraced street housing on Dale Street and Daisy Bank Street between Ash Street to the north and Rose Bank Street to the south.

Figure 2-1 Main Boundary

The boundaries are fed from the existing LV network via 3 main feeders. Underbank Close Way 6, Bankside Ln Way 3 and Boston Rd 453143 Way 6. There are also an additional 4 houses fed from Underbank Close way 5 and 1 house fed from Boston Rd way 4. The transformer rating and the houses applicable to this study are shown in Table 2-1.

Table 2-1 Feeding Distribution Substations

LV Feeder	Primary	Transformer	Terraced	Semi-Detatched
Underbank Cl Way 6	Wesley Place	750kVA	80	4
Underbank Cl Way 5	Wesley Place	750kVA		4
Bankside Ln Way 3	Wesley Place	500kVA	10	
Boston Rd Way 6	Wesley Place	800kVA	12	2
Boston Rd Way 4	Wesley Place	800kVA	1	
			103	10
			113	

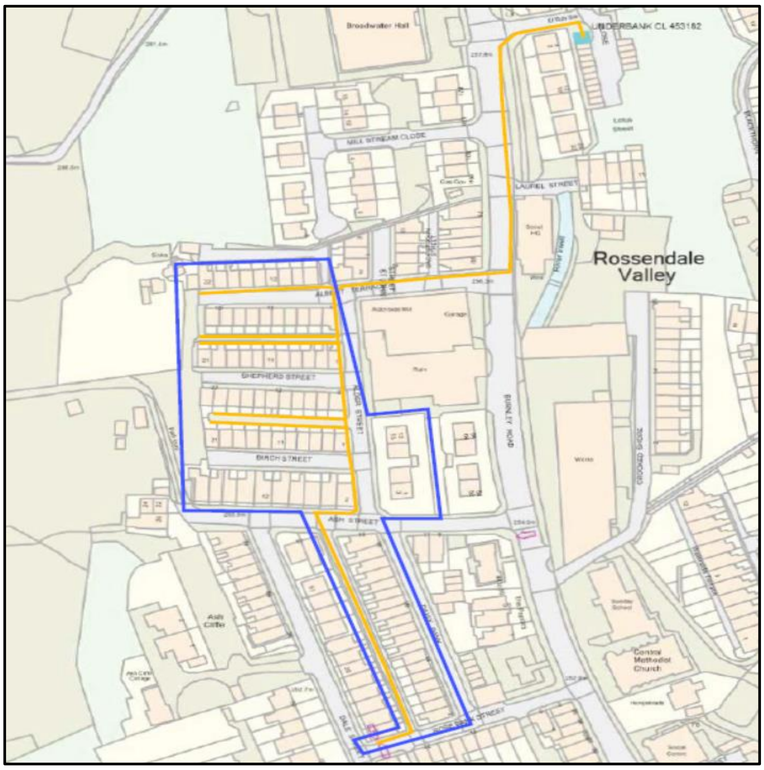


Figure 2-2 Underbank Close Way 6

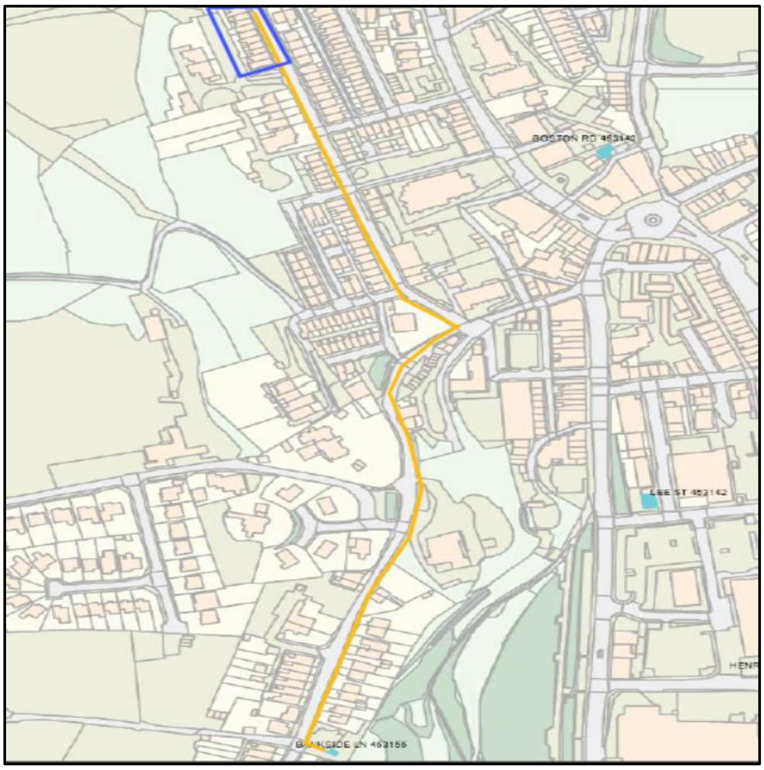


Figure 2-3 Bankside Lane Way 3

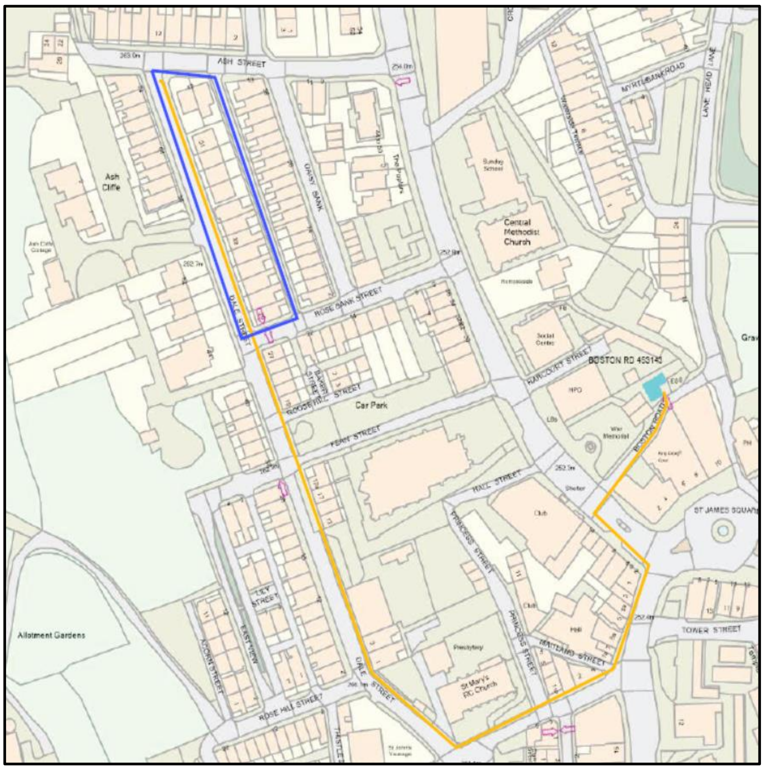


Figure 2-4 Boston Road Way 6

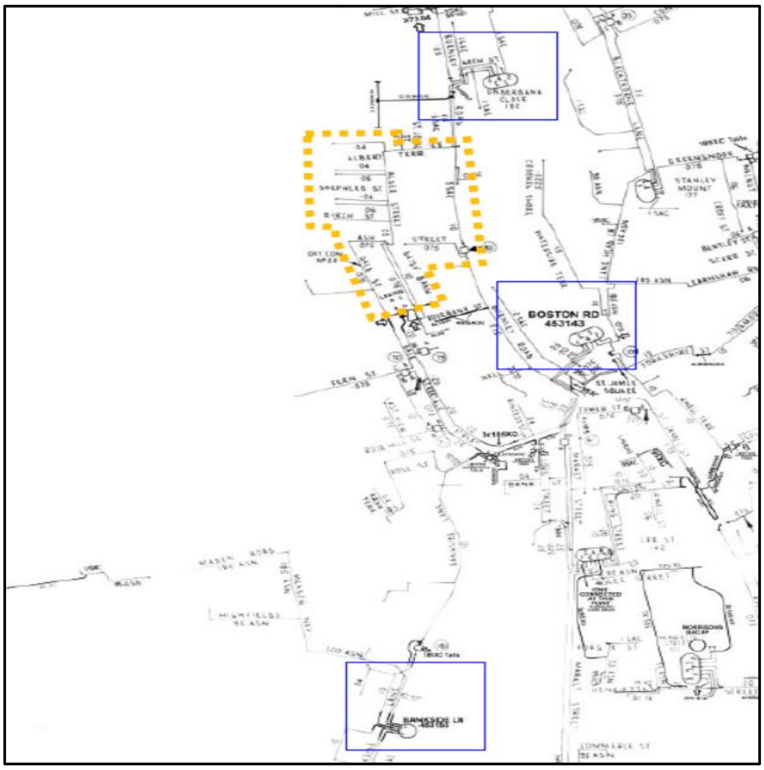


Figure 2-5 Existing LV Network

3 Counterfactual

The Counterfactual for a heating system in terraced housing that acts as a direct comparison to the low carbon community heating is the option of using individual electric boilers. Accessibility in the market and their relative simplicity make them an ideal base case from which to carry out a comparison with more ambitious decarbonisation strategies.

Each individual dwelling's electric boiler shall be sized to meet the peak demand of the property without any retrofit. It would essentially take the role of the existing gas boiler within each property. Whilst there would not need to be any alteration to the building fabric and the replacement would be a simple 'like for like'. The system would be much lower in efficiency than a heat pump system resulting in higher energy costs.

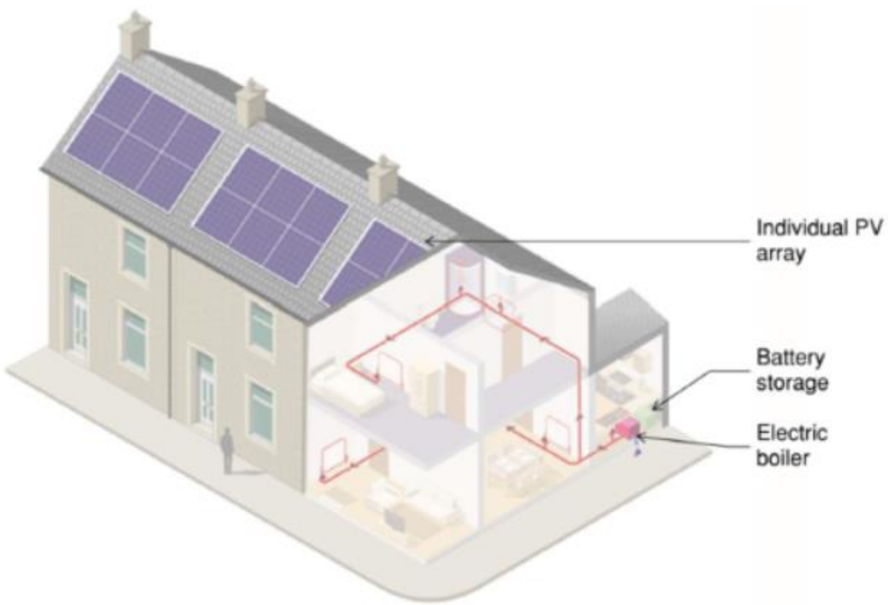


Figure 3-1 Counterfactual Option with Electric Boiler

Owners/tenants would install and operate their own electric boilers and have responsibility for purchasing the boiler at between 7-17kW depending on the house size, paying the electrical bill to power the boiler and all ongoing maintenance.

4 Heat Pump

The installation of Heat Pumps in terraced home is a known challenge due to space constraints and noise issues. An alternative basic solution to incorporate low carbon technologies in a terraced home is to simply replace the gas boiler heating system with an electric boiler. The disadvantage of this is that the system is less efficient than a heat pump system and the demand on the network is high. There would also be a lack of communal energy sharing capability.

A 5th generation shared ambient loop network is proposed which consists of an individual GSHP at each home connected via a common loop and boreholes drilled within the streets surrounding the properties. The water from the borehole array is circulated within the ambient loop and the individual GSHP's. For homes that lack the space requirements to install a hot water tank, Phase Change Material (PCM) thermal batteries can be installed as an alternative. The GSHP system is shown in Figure 4-1 along with the shared PV array.

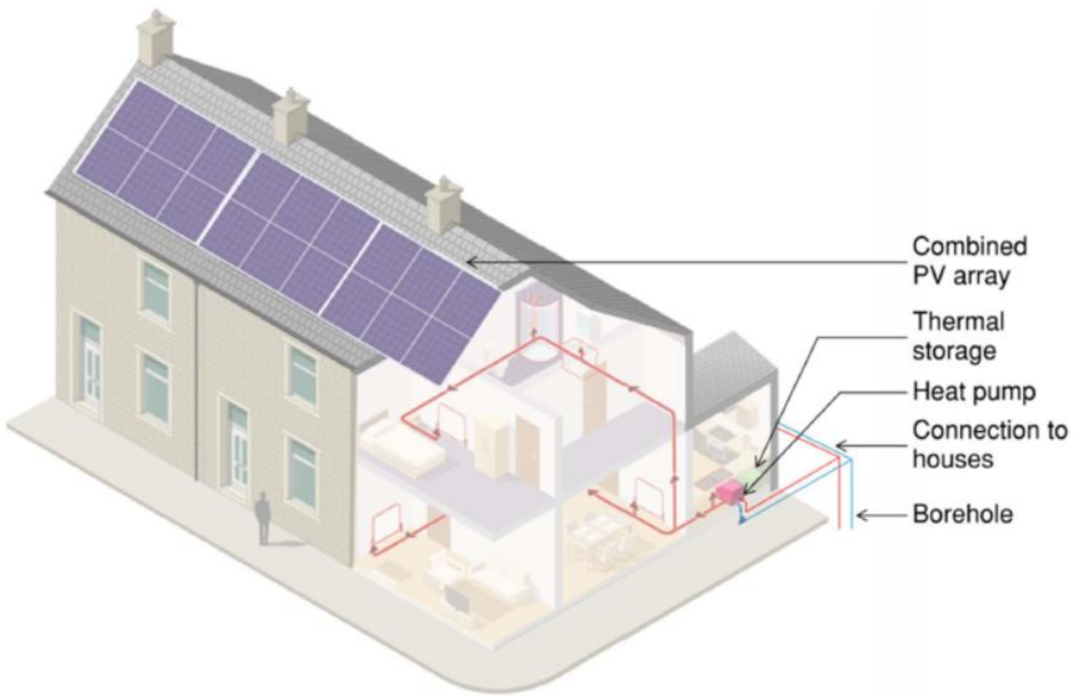


Figure 4-1 GSHP 5th Generation Shared Ambient Loop

4.1 LV Demand Design Principles

When assessing the available spare demand capacity on the LV network a simple assessment based on the (transformer rating – Maximum Demand Indication (MDI) reading) is not permitted.

The following design principles are taken from ENWL policy Electricity Policy Document (EPD) 283 'LV Network Design Manual':

- **Voltage Drop**
  Based on a Busbar voltage of 415/240V, the voltage drop from a distribution substation low voltage busbar to any customer's cut out shall not exceed 7% with the additional requirement that the voltage drop in the service connection shall not exceed 2%.

- **Earth-Fault Loop Impedance**
  It is necessary to ensure that the earth-fault loop impedance at each cut-out is sufficiently small to pass fault current to operate the cut-out fuse within 5s. The earth-fault loop impedance at any cut-out should not normally be designed to exceed 0.35Ω on a Combined-Neutral-Earth (CNE) distributor and not to exceed 0.8Ω on any distributor.

- **Thermal Overload of Transformers and Cables**
  Account shall be taken of the possible need for load-related reinforcement when:
  - A distribution transformer, which is already overloaded, e.g. sustaining a cyclic loading in excess of 130% of its nameplate rating or a continuous loading in excess of its nameplate rating
  - An LV distributor, which is already operating in excess of its rating (cyclic rating or continuous rating as appropriate).

Assessment of ADMD (After Diversity Maximum Demand (ADMD)

To assess the load on a LV feeder, the ADMD method is used. This establishes an expression to derive maximum demand for a group of customers based on an average kW value per customer based on the type of house, heating and any applicable LCT.

For a group of customers is it found in practice that the ADMD can be adequately calculated from the expression:

Maximum Demand = (aN + P) kW where:
A = average ADMD(kW) per customer
N = number of customers in the group
P = load allowance (kW) for loss of diversity

The values to be used for P are obtained from the recommended values in ENA ER P5
- For single rate users P = 8kW
- For Economy 7 users P = 4kW

The design levels of ADMD to be used in this project are shown in Table 4-1:

Table 4-1 ADMD Per Customer

	ADMD Per Customer (kW)	
Property Type	Day	Night
Small Non-Electric Non-Detatched	1.0	0.4
Non-Electric Detatched	1.4	0.6
Electric Heating	3.4	2.4
Heat Pump (HP)	Values as Per ENA EREC P5	

4.2 GSHP ADMD

The chosen heat pump for this project is the Shoebox GSHP made by Kensa. This is a compact unit ideal for homes such as terraces and apartments. The heat pump output rating comes in either 3kW or 6kW. The 6kW option for this project is suitable. The 6kW equating to 26.1A per phase at 230V is below the 32A per phase requirement to come under BS EN 61000-3-2. More information on the requirements to connect a Heat Pump can be found here. In this case a connect and notify approach is not possible due to the cumulative effect of all the heat pumps that will need to be assessed on the network.

Values as Per ENA EREC P5

The ADMD for a single 6kW heat pump is 4.90 under normal conditions. When considering a '1 in 20' winter day scenario this can be increase by a factor of 1.5 to 7.37kW. For a 'cold pickup' scenario the 4.90kW value can be doubled to 9.80kW. The ADMD will however decrease by aN^b for the next heat pump where a is the ADMD for the first heat pump and b is a factor of -0.20 as stated in ENA ER P5 issue 6.

For example, if there are 10 heat pumps connected when considering the average winter group demand, the ADMD of the tenth heat pump would be 4.90*10^-0.20 = 3.09kW. However, the group demand would be 36.59kW.

The cumulative effect of the ADMD will have to be split into how many heat pumps are on each of the five LV feeders combined with the ADMD per house and the loss of diversity allowance. This can be seen in the table below. Note this table does not include the additional contribution from the remaining houses on the feeders that are not in the study.

Table 4-2 ADMD for Kensa Shoebox 6kW GSHP

6kW Heat Pump	Factor a	Factor b
Average Winter	4.90	-0.2
1-in-20 winter	7.37	-0.2
Cold pick-up A	9.81	-0.2

Usually if more than 20% of customers would be fed from a heat pump, the in-line heater should be accounted for, however the Kensa Shoebox heat pumps do not have a built-in heater, so the next conservative estimate is the 1 in 20 ADMD.

4.3 Proposed Demand

The homes in the study are in the conservation area of Bacup Town Centre. There are 113 dwellings consisting of 103 terraces and 10 semi detatched. The existing heating systems installed in most of the homes are natural gas combi boilers. The total demand from the development utilising the Electric Boiler (counterfactual) option can be seen in Table 4-3 and the GSHP option in Table 4-4

Table 4-3 Total Demand from Development using Electric Boilers

LV Feeder	No. of Houses	ADMD per house (kW)	Loss of Diversity (kW)	Group Demand (kW)
Bankside Ln Way 3	10	3.4	8.00	42
Underbank Cl Way 6	84	3.4	8.00	293.6
Underbank Cl Way 5	4	3.4	8.00	21.6
Boston Rd Way 6	14	3.4	8.00	55.6
Boston Rd Way 4	1	3.4	8.00	11.4
				424.2

Table 4-4 Total Demand from Development using GSHP's

		Average Winter		**1-in-20**			
LV Feeder	**No. of GSHP's**	**ADMD (kW)***	**Group Demand (kW)**	**ADMD (kW)***	**Group Demand (kW)**	**Loss of Diversity (kW)**	**Total**
Bankside Ln Way 3	10	3.09	36.59	4.65	55.04	8.00	63.04
Underbank Cl Way 6	84	2.04	209.51	3.04	315.12	8.00	323.12
Underbank Cl Way 5	4	3.71	16.81	5.59	25.29	8.00	33.29
Boston Rd Way 6	14	2.89	48.43	4.35	72.84	8.00	80.84
Boston Rd Way 4	1	4.90	4.90	7.37	7.37	8.00	15.37
							515.66

*These values differ slightly in LV AFFIRM

4.4 Penetration of Low Carbon Technologies (LCTs) on feeders

EPD 283 'LV Design Manual' states that 'ADMDs associated with clusters of LCTs may vary considerable according to customer behaviour and usage patterns. Academic research has indicated thresholds that limit the penetration of LCTs before network reinforcement may be required. Network monitoring shall be fitted to record voltage and demand levels when LCTs reach penetration levels as per Table 4-5. It is also anticipated in the future that Harmonics monitoring will need to be at LV substations and this will be necessary as more LCT's come onto the network.

Table 4-5 LV Monitoring Threshold

LCT Type	Threshold	Monitor
HPs (3.6kW)	10%	Demand and voltage at LV board using smart fuse
EVs (3.6kW)	10%	Demand and voltage at LV board using smart fuse

Table 4-6 Required LV Monitoring per feeder

Feeder	No. of GSHP's	No. of Houses	LCT Penetration (%)	Threshold exceeded
Bankside Ln Way 3	10	107	9.4	No
Underbank Cl Way 6	84	116	72.4	Yes
Boston Rd Way 6	14	55	25.5	Yes

4.5 LV Assessment

LV AFFIRM – Network Design Workbook

The preferred method of calculation to be used in the design of the LV network is LV AFFIRM, an in house ENWL Microsoft excel workbook which based on inputs, such as transformers, cables and customer ADMD values, calculates the design principles as described in section 3.1 and states if compliance has been met.
Each section of cable on the LV main will be entered onto LV AFFIRM along with the associated houses on that particular section. Any houses that contain Heat Pumps will have the ADMD updated accordingly. The total voltage drop can then be seen along with any thermal ratings that have been exceeded. **The assessment will focus solely on the three main feeders with Underbank Close Way 5 and Boston Road Way 4 not studied, however this would need to be completed at a later date.**

The ADMD per GSHP differs slightly on LV AFFIRM when compared to Table 4-4 and can been seen in the Table 4-7.

Table 4-7 LV AFFIRM GSHP

Feeder	No. of GSHP's	ADMD (kW)	House + HP ADMD (kW)
Bankside Ln Way 3	10	3.67	4.70

Feeder	No. of GSHP’s	ADMD (kW)	House + HP ADMD (kW)
Underbank Cl Way 6	84	1.55	2.50
Boston Rd Way 6	14	3.47	4.50

Table 4-8 Results from Electric Boilers

Feeder	Total Distributor Load (A)	Worst Case Voltage Drop (%)	Earth-Fault Loop Impedance (Ω)	Cable Thermal Overload	Transformer Thermal Overload
Bankside Ln Way 3	198	10.11	0.52	No	No
Underbank Cl Way 6	449	6.5	0.22	No	N0
Boston Rd Way 6	135	3.58	0.32	No	No

Table 4-9 Results from GSHP's

Feeder	Total Distributor Load (A)	Worst Case Voltage Drop (%)	Earth-Fault Loop Impedance (Ω)	Cable Thermal Overload	Transformer Thermal Overload
Bankside Ln Way 3	216	11.49	0.52	No	No
Underbank Cl Way 6	350	5.00	0.22	No	N0
Boston Rd Way 6	155	4.29	0.32	No	No

4.6 Comments

The voltage is outside of the statutory limits on the Bankside Ln Feeder for both the electric boiler and GSHP option due to the small sections of cable in the circuit. The solution to mitigate this would be to overlay the cable with larger sections. By replacing the small sections, the circuit impedance will reduce, and the voltage will increase. The voltage drop has almost been exceeded with an electric boiler on the Underbank Cl feeder, however both remaining two feeders are within ratings both from a thermal and voltage perspective.

4.7 Budget Estimate for reinforcement

The costs in Table 4-10 are taken from the ENWL Budget Quote Ready Reckoner which is a simple high-level calculator which takes account of the required assets and associated overheads. In this case there is 979m of LV Mains Cable to overlay with an associated 81 services on the Bankside Ln feeder.

Table 4-10 Budget Costs

Feeder	Asset	Cost
Bankside Ln	LV Mains and Service Cable	£323000*
Underbank Cl	No Reinforcement Required	
Boston Rd	No Reinforcement Required	

*Cost includes 40% overhead

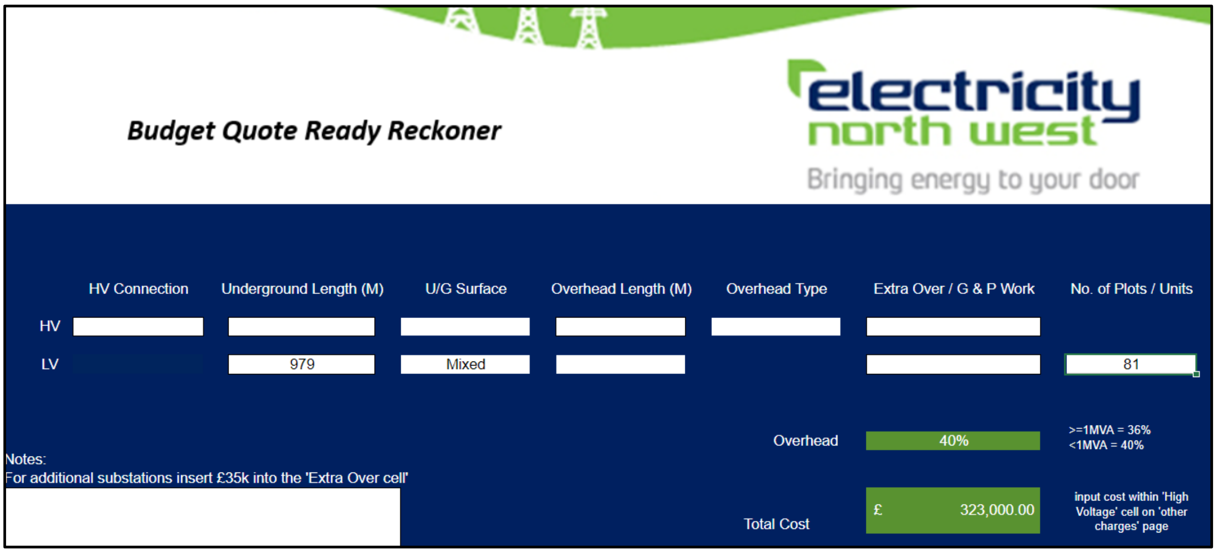


Figure 4-2 Budget Calculator

5 Solar PV

The most basic configuration for installing PV in a terraced home is an individual single dwelling owned array fed into the domestic meter. The system is owned by the homeowner and therefore the benefits only apply to each respective householder. In relation to a row of terraces houses, this would be expensive for all individuals as a cost would be incurred by each householder for the individual connection. It would also result in a lack of communal energy sharing capabilities making the full system size larger.
An additional consideration was to install Battery Storage inside each home to utilise some of the electricity from the array when demand in the home is low. Batteries are a good way to store any PV generated energy that is not consumed on site at the time of generation. It was however determined that that batteries do not appear to be commercially viable as a storage option largely due to the capital expenditure and replacement costs involved with these. The storage of energy instead through thermal storage was deemed to be a more viable commercial model.

5.1 Connection Options

The approach in the SIF project is to utilise a shared community owned PV array across a row of terraced homes. The shared array will be owned by the community energy company with the installation, operation and maintenance costs being recouped through the costs of exported power sold into the network by the company.
The array can be connected to the network in either two ways, a private wire individual connection behind the meter to each home shown in Figure 5-1 or a direct connection to the network via an LV POC as shown in Figure 5-2.
Although power sharing is possible in the private wire configuration, the net exported electricity onto the grid will likely be lower due to greater self-consumption in the homes. As each home would require an individual private connection, this would result in a higher initial cost when compared to the direct connection to the network. Using the direct connection would require the least infrastructure to distribute the electricity as the existing LV electricity network is used.

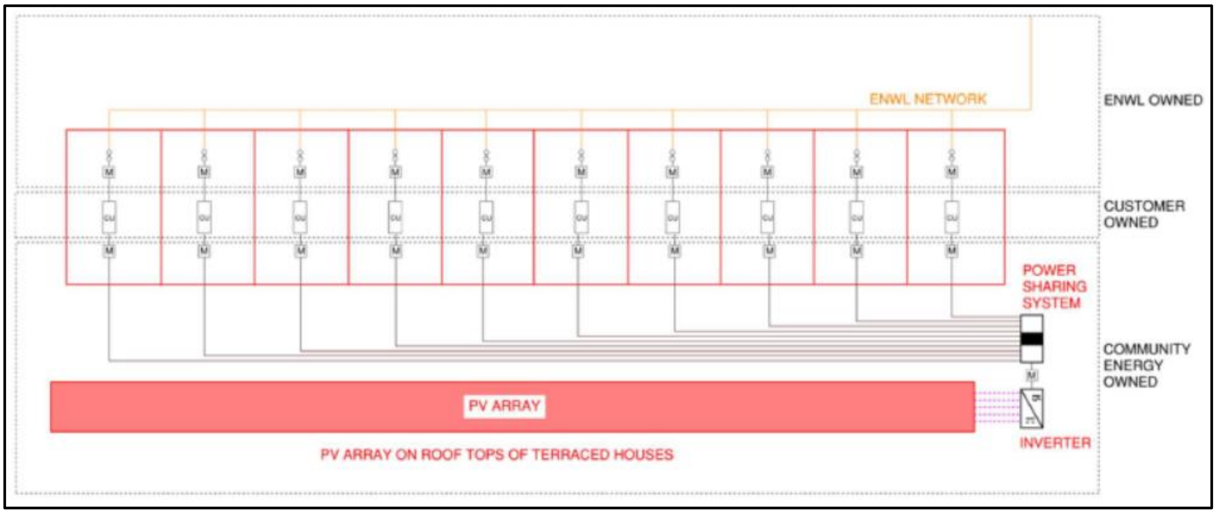


Figure 5-1 Solar PV - Private Wire Connection

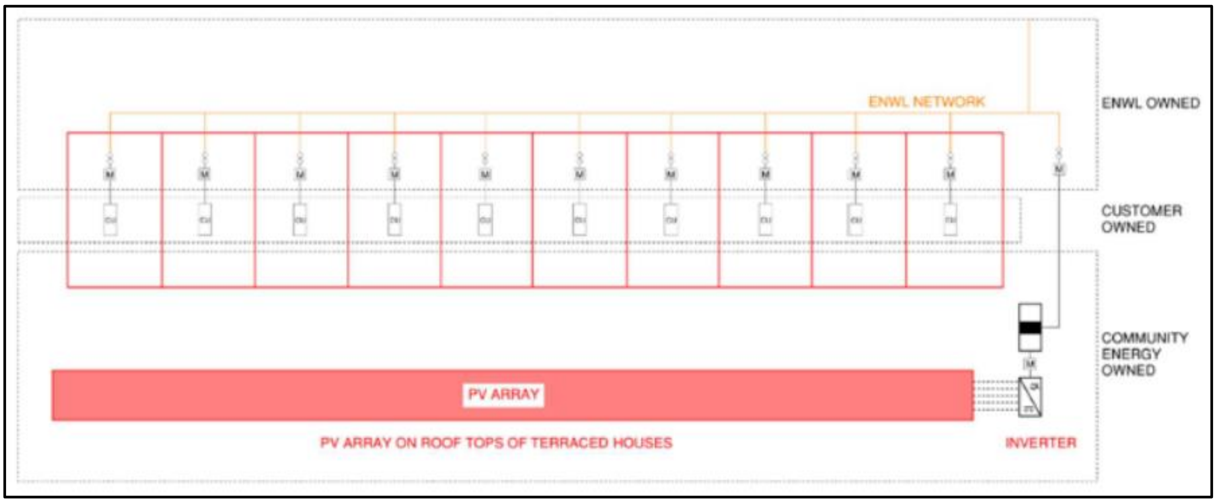


Figure 5-2 Solar PV - LV POC to the ENWL network

5.2 LV Generation Design Principles

When assessing whether generation can be added onto the LV network the following design principles apply according to ENWL EPD 283.

Statutory Voltage Limits

The declared voltage is required to be 400/230V plus 10% minus 6% unless otherwise agreed with the customer

Prospective Short Circuit Current (PSCC)

For connections derived from a single 1000kVA transformer the maximum PSCC, at the customer's terminals is not expected to exceed the following values:

- Three phase = 27kA
- Single phase = 16kA

Parallel Generation

Where any user's installation is to include a domestic generation appliance, the owner shall ensure that the installation complies in all respects with EREC G98 and EREC G99

5.3 Assessment of Minimum Average Demand (MAD)

When assessing generation on the LV network the Minimum Demand per customer using the Minimum Average Demand (MAD) method shall be used to calculate the total demand of both the existing and the new customers that are supplied from an LV distribution substation in the Minimum Regime.
For a group of customers supplied from an LV distribution substation, the total demand in the Minimum Regime shall be calculated from the following expression taken from ENWL COP221 'Low Voltage Network Design for Domestic Premises with Microgeneration:

Minimum Demand = (N.*d) kW, where N = number of customers in the group and d = MAD per customer (kW). In this instance a Minimum Demand value of 0.31kW per customer, applicable to PV will be used.

Table 5-1 MAD Per Customer

	MAD per customer (kW)		
Load Category	DCHP, FCCHP & MicH	FC & MicW	PV
Domestic Unrestricted	0.17	0.16	0.31
Domestic Economy 7	0.45	0.23	0.21

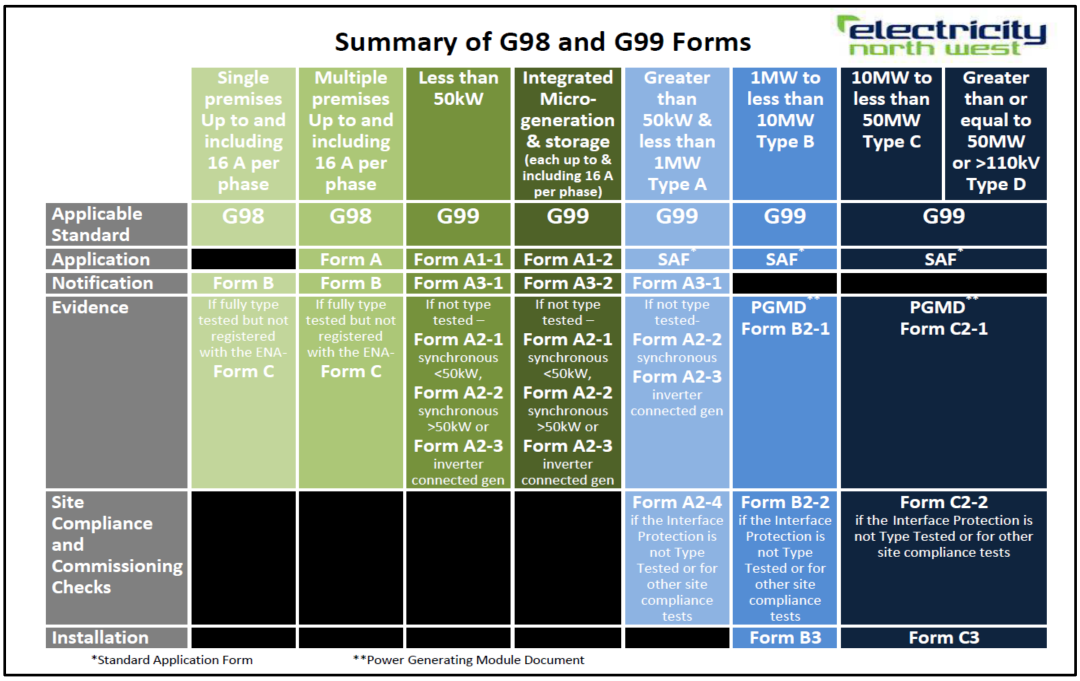
5.4 G99 Requirements

ENA EREC G99 details the technical requirements for Power Generating Modules to connect in parallel with public distribution networks on or after 27th April 2019. The requirements are for any Module greater than 16A per phase.
The PV will be classes as a type A Power Park Module which is classed as a module that is either asynchronously connected to the network or connected through power electronics such as an inverter. The type A refers to a module with a connection point below 110kV and a registered capacity of 0.8kW or greater but less than 1MW.
The Solar PV array must be full type tested with G99 and have a manufacturer's reference number available. This can be included on the application form along with the export capacity and predicted running arrangements i.e. long-term parallel operation.

Before the PV is commissioned, certain tests need to be carried out and witnessed including:

- Output power with falling frequency
- Over frequency
- Fault Ride Through and Phase Voltage Unbalance
- Voltage Limits and Control

Further information on G99 requirements is available here. The summary of G98/G99 requirements can be seen in Figure 5-3.



Summary of G98 and G99 Forms

	Single premises Up to and including 16 A per phase	Multiple premises Up to and including 16 A per phase	Less than 50kW	Integrated Micro-generation & storage (each up to & including 16 A per phase)	Greater than 50kW & less than 1MW Type A	1MW to less than 10MW Type B	10MW to less than 50MW Type C	Greater than or equal to 50MW or >110kV Type D
Applicable Standard	G98	G98	G99	G99	G99	G99	G99	
Application		Form A	Form A1-1	Form A1-2	SAF*	SAF*	SAF*	
Notification	Form B	Form B	Form A3-1	Form A3-2	Form A3-1			
Evidence	If fully type tested but not registered with the ENA- Form C	If fully type tested but not registered with the ENA- Form C	If not type tested – Form A2-1 synchronous <50kW, Form A2-2 synchronous >50kW or Form A2-3 inverter connected gen	If not type tested – Form A2-1 synchronous <50kW, Form A2-2 synchronous >50kW or Form A2-3 inverter connected gen	If not type tested- Form A2-2 synchronous Form A2-3 inverter connected gen	PGMD** Form B2-1	PGMD** Form C2-1	
Site Compliance and Commissioning Checks					Form A2-4 if the Interface Protection is not Type Tested or for other site compliance tests	Form B2-2 if the Interface Protection is not Type Tested or for other site compliance tests	Form C2-2 if the Interface Protection is not Type Tested or for other site compliance tests	
Installation						Form B3	Form C3	

*Standard Application Form **Power Generating Module Document

Figure 5-3 G98/G99 Summary

5.5 Proposed Generation

The Array Size and the associated number of dwellings for each array is shown Table 5-2 which was taken from the feasibility study undertaken by Buro Happold when considering the Solar PV without any Storage option.

Table 5-2 Solar PV Array Sizes

Area name	Array Size (kW)	Number of dwellings	Associated Feeder
Near Albert Terrace	14	9	Underbank Cl Way 6
Back Alley – Near Albert Terrace	17	10	Underbank Cl Way 6
Near Shepherd Street	19	11	Underbank Cl Way 6
Back Alley – Near Shepherd Street	17	11	Underbank Cl Way 6
Near Birch Street	14	11	Underbank Cl Way 6
Near Ash Street	28	10	Underbank Cl Way 6
Near Dale Street	8	10	Bankside Ln Way 3
Two Houses – SE Facing and Near Sale Street	2	2	Boston Rd Way 6
Near Back Alley	34	12	Boston Rd Way 6
Near Daisy Bank	28	19	Underbank Cl Way 6
Full Site	**181**	**105**	

5.6 Permissible Voltage Rise

The maximum permissible voltage at any point on the LV network is 230V +10%/-6% = 253V/216V which are the statutory limits.

The extent of the voltage rise on the LV nodes is dependent on the voltage from the HV network. The statutory limit for voltage rise from the HV system would be +6% which would increase the nominal 11kV voltage to 11.6kV and the 6.6kV voltage to 7.0kV. However, the voltage can be reduced on the distribution substation by changing the taps. There are generally 5 taps with the most common tap position being 3. In certain areas of the network where the primary volts are high, the tap position can be as low as 1 to attempt to lower the voltage.

The voltage profile for Wesley Place primary in summer 2022 is shown in Figure 5-4. The profile has a nominal voltage of 6.6kV and has a maximum voltage of 7.06kV on September 16th at 12:05pm. The minimum voltage is 6.53kV which occurred on June 16th at 14:57pm. Generally, the export from a PV array can be expected between the peak sun hours of 11:00 – 15:00, therefore, the maximum and minimum voltage that occurred is valid to be used in the study.

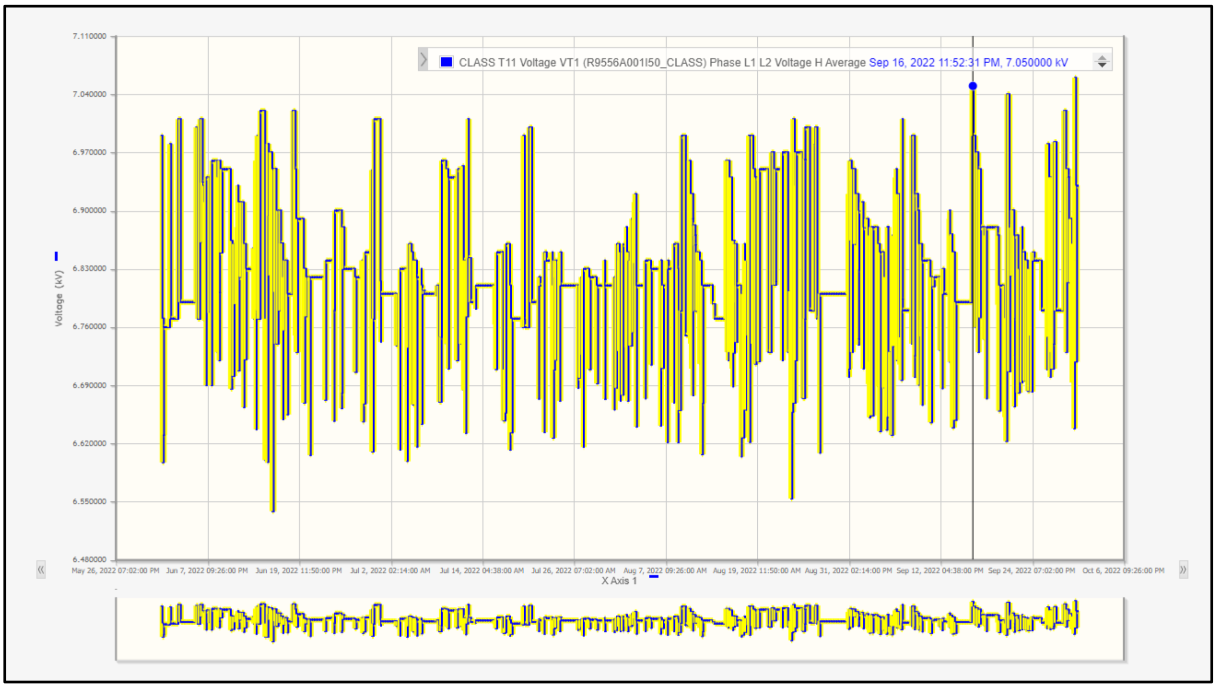


Figure 5-4 Summer Demand Profile for Wesley Place Primary

The profile does highlight in particular that the voltage at Wesley Place Primary is higher than nominal. One of the issues with obtaining the voltage at the primary busbar level is that the Automatic Voltage Control (AVC) relays are controlled by CLASS which is monitoring the network and adjusting the tap changers to reduce demand during peak loads. Therefore, the voltages observed in the profile may not be reflective of the system demand but of the change of Primary Transformer tap position to reduce demand. A sensible assumption in this case will be to assume the HV Voltage is nominal.

The voltage drop from the HV Primary Busbar to the Distribution Substation at low load is taken to be 0.2 and the high load is taken to be 1.5 which are common values for urban areas.

5.7 LV Assessment

Using the LV AFFIRM spreadsheet under the 'MicroGeneration' tab a MAD for each house on the associated feeder can be entered and the PV arrays can be connected onto their respective sections of cable.

The high voltage impact of each PV array can be assessed by connecting the total capacity of the array into a service at the upstream end of the section it is connecting to. Generally, the further downstream the array is on the section, the higher the voltage will be at that node. Therefore, if the upstream section fails then the likelihood is that the downstream will fail.
If the upstream and downstream sections both fail, then the sleeved array option would not be possible without reinforcement. The private wire option may still be applicable provided splitting the feeder and modelling the voltage at each service is acceptable.

Bankside Ln Way 3

This is a particularly long feeder with significant sections of small 0.075 Cu PILC cable. The section feeding the 10 dwellings is the last on the main. Whilst the high voltage is within limits, the low voltage is shown as amber as some new equipment will likely be rated >220V. The low voltage exceedance is cause by the load and is an external issue to the generation.

Single-Phase Connections			Others on	Results		
	MAD (kW)	Gen (kW)	S/S	High V	Low V	Pass/Fail
Type A	0.31	8		251.3	219.1	
Type B	0.31					
Type C	0.31					

Figure 5-5 Bankside Ln Array on Tap 2

Underbank Cl Way 6

The cumulative 137kW is a significant amount of PV proposed to be connected onto this feeder. This equates to 595A at 230V. The total MAD is 0.33kW * 116 houses = 38.28kW which equates to 53A at 415V. Therefore, with 542A potentially flowing upstream of the PV, there are sections of 0.25Cu and 95 Waveform whose thermal ratings will be exceeded. With all PV arrays connected, the voltage at numerous nodes is exceeded at a minimum tap setting of 1 which can be seen in Figure 5-6 highlighted in red.

Line Sect'n	3φ End MAD (kW)	3φ End Gen (kW)	1φ End Node MAD (kW)	1φ End Node Gen (kW)	Dist'd MAD (kW)	End Node MAD (kW)	High V at End Node (V)
A							239.2
B					0.66		239.2
C							240.8
D							243.0
E					1.54		243.0
F							243.9
G					0.22		247.4
H							248.7
J					0.44		248.7
K					0.33		251.1
L					1.21		251.0
M				31	0.11		253.0
N					0.99		252.9
P							253.3
Q					1.1		253.2
R				36	0.22	0.11	256.2
S					1.1		256.1
T							256.4
U				14	1.1		258.8
V					0.33		256.9

Line Sect'n	3φ End MAD (kW)	3φ End Gen (kW)	1φ End Node MAD (kW)	1φ End Node Gen (kW)	Dist'd MAD (kW)	End Node MAD (kW)	High V at End Node (V)
ZA				28	0.99		261.7
ZB					0.33		257.3
ZC				28			257.8
ZD					1.98		257.7
ZE							
ZF							
ZG							
ZH							
ZJ							
ZK							
ZL							
ZM							
ZN							
ZP							
ZQ							
ZR							
ZS							
ZT							
ZU							
ZV							

Figure 5-6 Underbank Cl All PV Arrays connected

With the Daisy Bank, Ash Street and Birch Street array connected, the voltage remains within the required limits, however with the addition of the Shepherd Street Array, the voltage is exceeded. This is with taps set to 1, therefore no other mitigation is available except network reconfiguration.

Boston Rd Way 6

The 36kW array is on the last section of the feeder. The voltage is within the required limits on the upstream end of the section at a tap setting of 1 but on the downstream it has been exceeded on a tap setting of 1 as seen in figure 5-10.

Single-Phase Connections	MAD (kW)	Gen (kW)	Others on S/S	High V	Results Low V	Pass/Fail
Type A	0.31	36		247.2	225.1	
Type B	0.31					
Type C	0.31					

Figure 5-7 Boston Cl Upstream of Last Section

Single-Phase Connections	MAD (kW)	Gen (kW)	Others on S/S	High V	Results Low V	Pass/Fail
Type A	0.31	36		259.1	222.9	
Type B	0.31					
Type C	0.31					

Figure 5-8 Boston Cl Downstream of Last Section

The two semi-detached houses are at the end of the section have an array of 2kW. The remaining 12 houses have been split into 2.83kW per house making the total up to 34kW. With the PV split along the feeder the voltage remains within the limits on a tap setting of 1 until the fourth dwelling as seen in figure 5-11.

Line Sect'n	3φ End MAD (kW)	3φ End Gen (kW)	1φ End Node MAD (kW)	1φ End Node Gen (kW)	Dist'd MAD (kW)	End Node MAD (kW)	High V at End Node (V)
A					1.0333		239.0
B							240.2
C					0.1033		240.3
D					0.2067		240.3
E					0.5167		240.2
F					0.1033		241.1
G							241.3
H							241.4
J					0.4133		243.3
K					0.4133		244.4
L							244.4
M						0.21	244.4
N					0.4133		245.2
P							245.3
Q							245.4
R							245.6
S					0.8267		245.6
T							251.5
U							
V							

Line Sect'n	3φ End MAD (kW)	3φ End Gen (kW)	1φ End Node MAD (kW)	1φ End Node Gen (kW)	Dist'd MAD (kW)	End Node MAD (kW)	High V at End Node (V)
ZA				2.83	0.1033		251.9
ZB				2.83	0.1033		252.3
ZC				2.83	0.1033		252.7
ZD				2.83	0.1033		253.1
ZE				2.83	0.1033		253.4
ZF				2.83	0.1033		253.7
ZG				2.83	0.1033		253.9
ZH				2.83	0.1033		254.1
ZJ				2.83	0.1033		254.3
ZK				2.83	0.1033		254.4
ZL				2.83	0.1033		254.6
ZM				2.83	0.1033		254.7
ZN				1	0.1033		254.7
ZP				1	0.1033		254.7
ZQ							
ZR							
ZS							
ZT							
ZU							
ZV							

Figure 5-9 PV distributed along feeder

5.8 Comments

The voltage is outside of the statutory limits on all three LV feeders.

The Bankside Ln feeder whilst not strictly outside of limits due to the PV has exceeded on low voltage due to the load connected to the high impedance feeder from small section cables.
The Underbank Cl feeder has a proposed 137kW of PV connected to it which alone exceeds some of the smaller section cables upstream of the PV after considering the MAD. The PV is connected onto the lower half of the feeder where the demand is lower which enables the voltage to rise more easily. For instance, if the PV was connected to the first section, the full 132kW can be taken without

exceeding the voltage rise (not considering the thermal ratings of the cables). The only way to get around this is to reconfigure the feeders or design a new section of network.
The Boston Rd feeder has a similar issue to Underbank Cl. The high voltage has been exceeded due to the light load at the end of the feeder. As above, reconfiguring the network will likely be the only solution to solve this.

5.9 Budget Estimate Budget Estimate for reinforcement

The costs below in Table 5-3 are taken from the ENWL Budget Quote Ready Reckoner which is a simple high-level calculator which takes account of the required assets and associated overheads. In this case a new HV substation will be required and new 2 x 200 LV feeders situated closer to the source of generation.

An assumed 2 x 15m loop-in connection to the HV network with 3 x 200m LV feeders.

Table 5-3 Budget Costs

Feeder	Asset	Cost
Bankside Ln	Unable to Accommodate due to loading – See Table 3-8	
Underbank Cl	New HV Substation & 2 x new LV Feeders - £380,000	
Boston Rd		

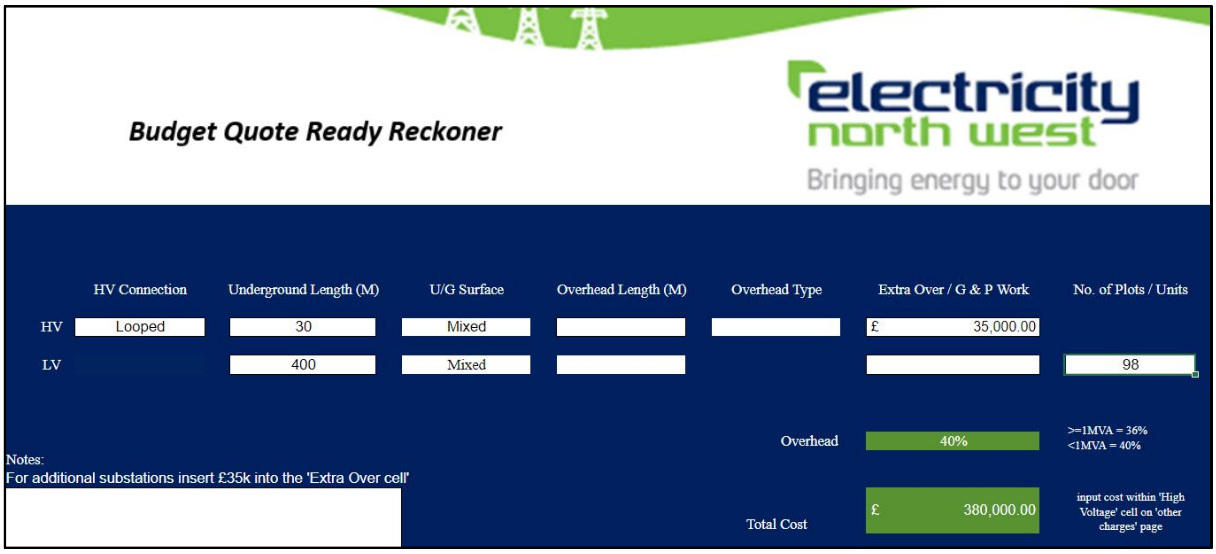


Figure 5-10 Budget Calculator

6 Budget for Total Reinforcement

To solve the load issue on Bankside Ln and the generation issue on the remaining two feeders, the total cost is assumed in Table 6-1.

Table 6-1 Budget for Total Reinforcement

Feeder	Asset	Cost
Bankside Ln	New HV Substation & 3 x new LV Feeders - £438,000	
Underbank Cl		
Boston Rd		

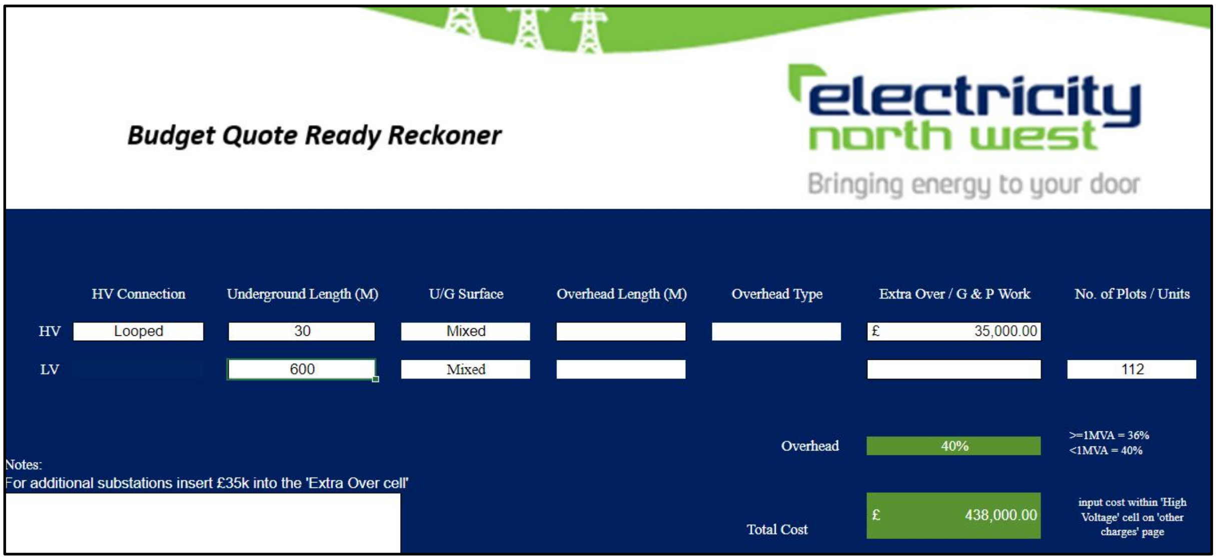


Figure 6-1 Budget Calculator for Total Reinforcement Cost

To submit an application to connect and view options for quotations click here.

There has recently been a change in the way costs are apportioned for reinforcement under the Access Significant Code Review (SCR). From 01/04/2023 any reinforcement associated with a demand connection is fully funded by the Distribution Network Operator (DNO) via Distribution Use of System (DUoS) charges. With a new generation connection, the reinforcement is fully funded at a connection voltage +1 above the PoC but the cost is still apportioned at the PoC level. More information on this can be found in section 8.

The Common Charging Methodology which details further information can be viewed here.

7 HV Reinforcement

For the GSHP's, the connection could proceed onto the LV network except for the Bankside Ln feeder, but it is the PV that limits the options for connection. A lot of the PV arrays are located far downstream on the mains cable and this causes a high voltage outside of statutory limits. The only real solution to this is to reconfigure the network from a new HV substation with LV feeders situated closer to the houses.

7.1 Existing Network

All the distribution substations in the area are fed from the 6.6kV network out of Wesley Place primary.

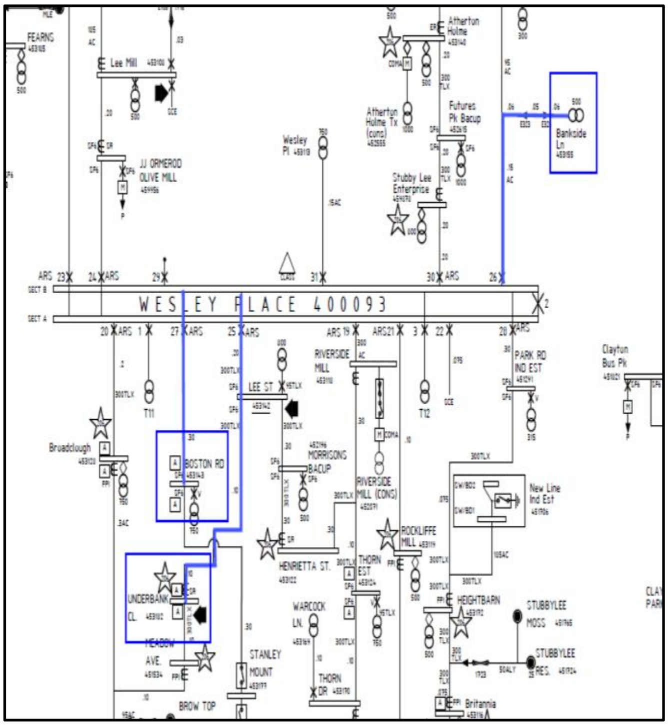


Figure 7-1 Existing 6.6kV Network

The Firm capacity and demands according to the latest Distribution Future Electricity Scenarios (DFES) forecasts for Wesley Place are shown in the Table 7-1.

Table 7-1 Primary Capacity

Primary	Firm Capacity (MVA)	Demand FY22	Demand FY28	Spare Capacity FY28
Wesley Place	22.90	9.80	11.10	11.80

There is an existing 6.6kV running by the houses in the study along Alder St, Ash St and Dale St. This is fed from Wesley Place – Broadclough and has a clean standby circuit to Wesley Place – Lee St along with another standby circuit to Hareholme – Clarkeholme.

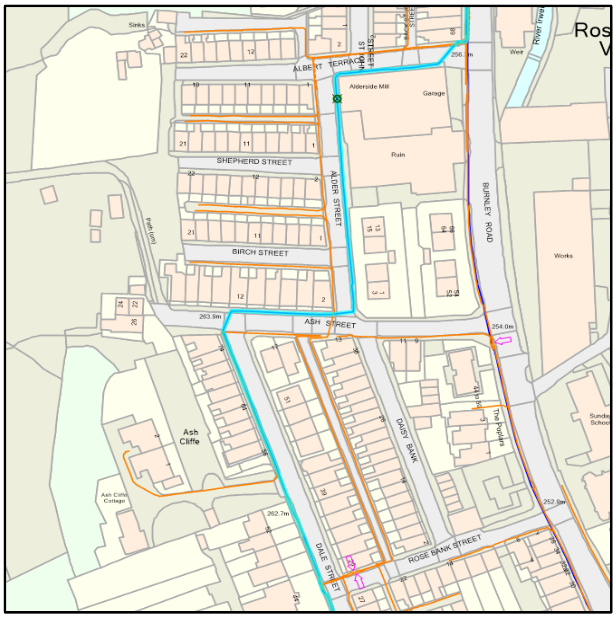


Figure 7-2 Potential HV Feeder to Loop onto

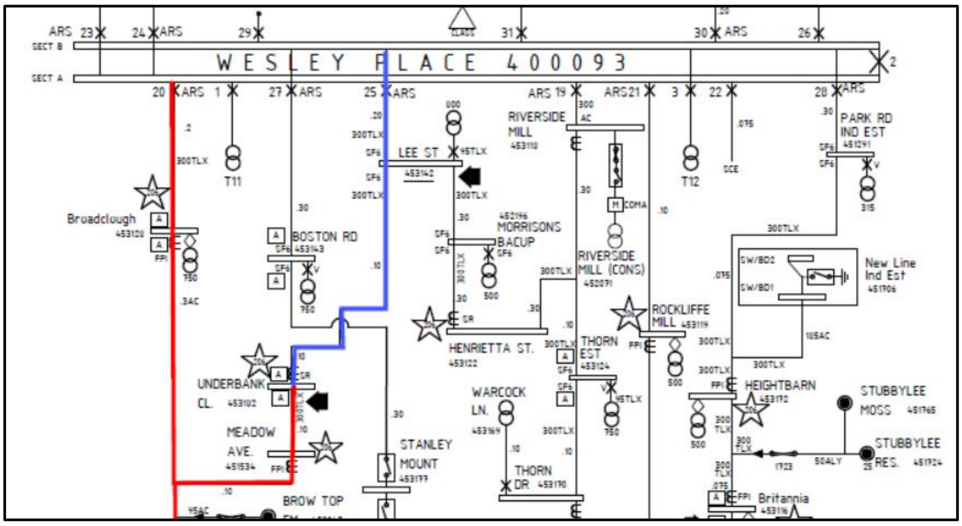


Figure 7-3 Proposed & Standby Feeder

7.2 Substation Position

To ensure that the voltage from the PV does not go over the statutory limit, the substation must be situated close to the existing houses. The old disused mill be a good option to situate the new substation. By positioning the substation close to the Mill, the LV cables can be kept to a minimum and have the highest chance of keeping the voltage low

However, the mill is a historical building which will likely need some refurbishment, the roof is open to the elements and the cost to refurbish the building is roughly estimated to be in the millions, based on the depth of refurbishment that would be required to bring it back into use.

In the Buro Happold feasibility study, the mill was proposed to be used for the energy centre option, however now as that is no longer going ahead the building could instead house the substation. It is understood that Valley Heritage has separate funding to explore options for the mill with a plan for refurbishment.

Figure 7-4 Waterside Mill - Roof in need of repair

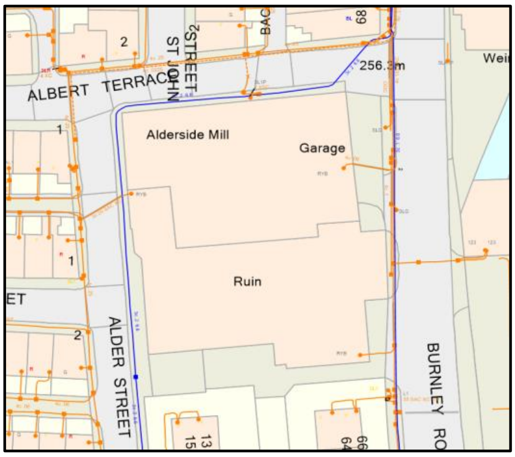


Figure 7-5 GIS Location of Waterside Mill

7.3 Feeder Loads

The latest feeder loads in FY22 were taken from the Network Management System (NMS) and can be seen in Table 7-2.

Table 7-2 Feeder Loads from NMS

Feeder	Load (A)	Cable 1st Section	CB Rating (A)	CT Rating (A)
Wesley Place - Broadclough	91	0.2Cu Pilc	400	400
Wesley Pl – Lee St	62	0.2Cu Pilc	400	400
Hareholme - Clarkeholme	78	0.2Cu Pilc	800	400

According to the latest R-Form diagram there are no proposed demand schemes and just 1 recently accepted scheme consisting of a new 200kVA PMT between Broadclough and Meadow Ave/Dog Pits Tee. The effect of this will be negligible. There is a HV metered customer at Scar End Generation on the Broadclough feeder which will be neglected for the demand study. On the Clarkeholme feeder, there is a HV Metered COMA customer at J.H. Hirst. This has an MIC of just 40kVA which should again be fairly negligible.

The outage scenarios are shown in Figure 7-6. All cables are within rating when considering the 516kVA extra capacity from the Heat Pumps on the network.

Outage scenarios

1			
Outage on:	Broadclough		
Pick up on:	Lee St		
Rating of feeder:	385 Amps	Using Distribution rating	
Total load on feeder:	203 Amps		
Acceptable:	YES	Spare amps:	182
Comments:			

2			
Outage on:	Lee St		
Pick up on:	Broadclough		
Rating of feeder:	385 Amps	Using Distribution rating	
Total load on feeder:	203 Amps		
Acceptable:	YES	Spare amps:	182
Comments:			

3			
Outage on:	Broadclough		
Pick up on:	Clarkeholme		
Rating of feeder:	385 Amps	Using Distribution rating	
Total load on feeder:	219 Amps		
Acceptable:	YES	Spare amps:	166
Comments:			

4			
Outage on:	Clarkeholme		
Pick up on:	Lee St		
Rating of feeder:	385 Amps	Using Distribution rating	
Total load on feeder:	140 Amps		
Acceptable:	YES	Spare amps:	245
Comments:			

Figure 7-6 Outage Scenarios

To assess the PV, only thermal and voltage drop needs to be considered on the normal running feeder with the fault level assessment done post acceptance. This can be done using DiNIS. The substation was situated adjacent to the Mill building where it is expected room will be available to accommodate the new substation.

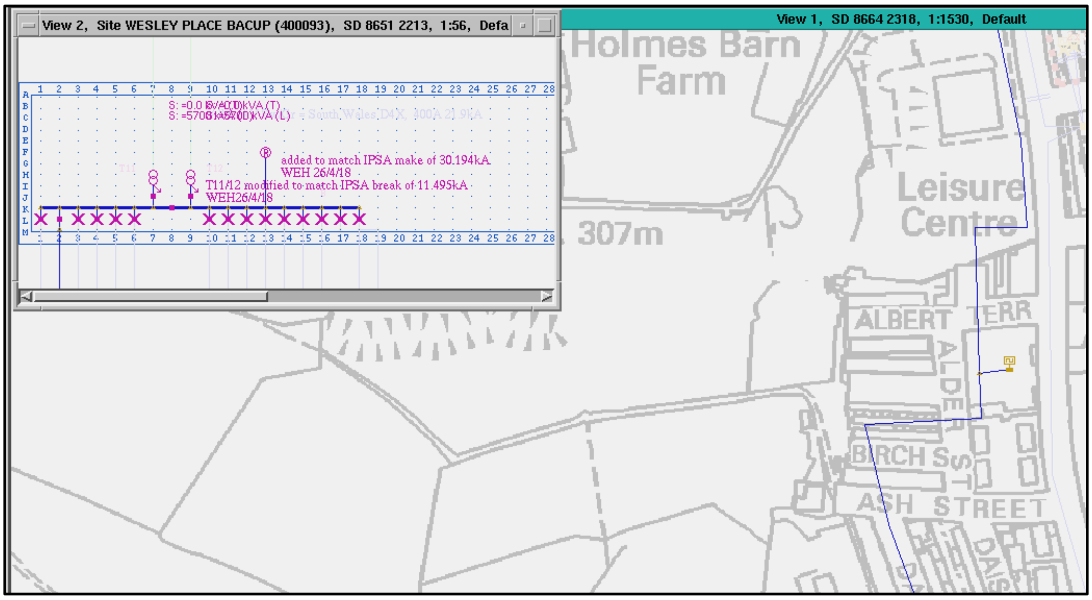


Figure 7-7 DiNIS Network

A minimum demand of 27.3A was taken as 1/3 of the total 91A. The voltage rise is minimal at 0.1% which is well within the 1.2% allowance.

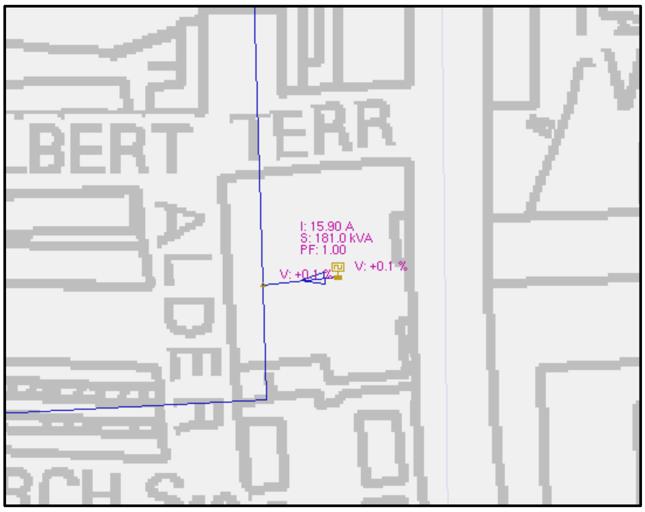


Figure 7-8 DiNIS Volt Drop Result

The proposed R-Form can now be seen below in Figure 7-9.

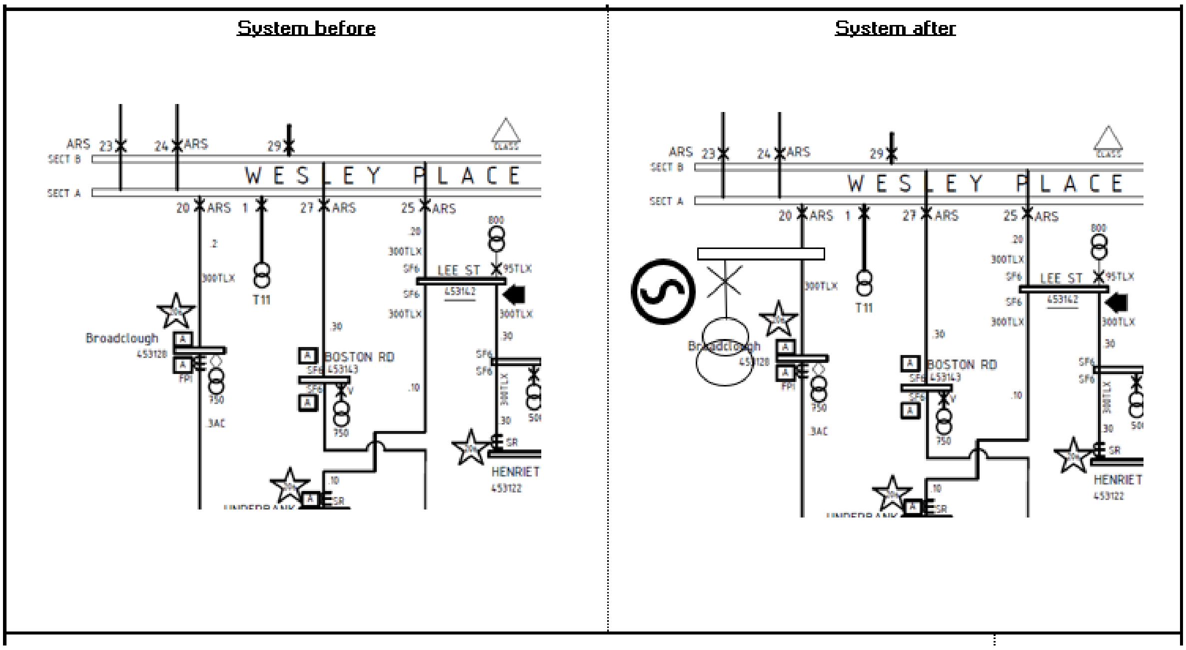


Figure 7-9 Proposed R-Form

The typical new LV substation design can be seen below. The maximum transformer size is 1000kVA, in this case a 750kVA transformer will be applicable with 6 x maximum 630A fuseways. All new cable will be 300Al Waveform.

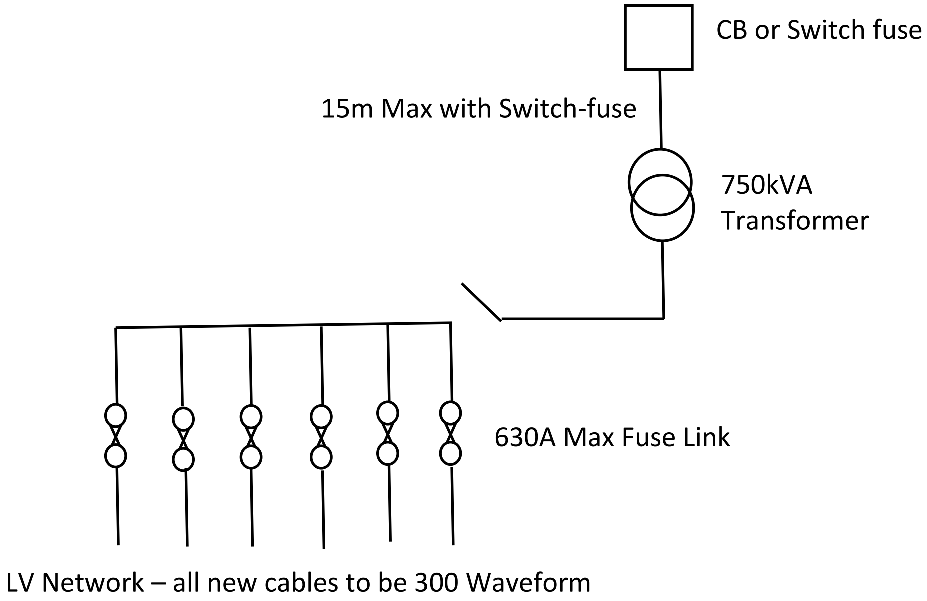


Figure 7-10 Proposed New LV Network

8 Flexibility Services

8.1 What are they?

Flexibility services is the term given to a procured service by which Distributed Energy Resource (DER) increase or reduce the amount of electricity they consume or generate onto the distribution network in line with a schedule or on receipt of a signal from the DNO. This helps DNO's manage constraints on the network when demand or generation is greater than the amount that the network is capable of safely providing.

In return for providing these services, providers receive a payment, which varies depending on the location of the constraint. This is because the costs available calculated based on the counterfactual solution, and so the reinforcement required to otherwise alleviate that constraint is studied on a case by case basis.

There are currently four types of flexibility services procured by DNO's within the UK, shown below. Because the services are used to alleviate different types of constraints, they have varying response times (e.g 15 mins or 2 mins) and different payment mechanisms (e.g. availability and utilisation, or just utilisation), however at ENWL we also accept energy efficiency as a response to the Sustain, Secure and Dynamic products as this helps to alleviate peak demand.

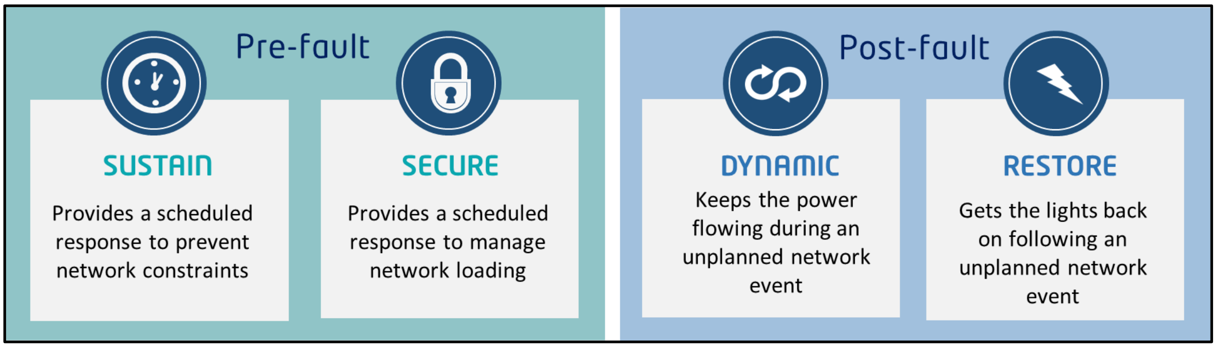


Figure 8-1 Flexible Service Options

8.2 How to take part?

All DNO's currently procure flexibility services, and in order to participate in a tender DER's need to be:

- Either already connected to the distribution network, or be connected to the distribution network by the beginning of the service window
- Compliant with Engineering Recommendation G98 or G99 for generation assets
- At least 50kW of generation or demand capacity, either directly connected, or as an aggregated portfolio. Note this applies to energy efficiency schemes too.
- Capable of flexing the consumption or generation of the connected asset

Full details of the technical requirements are available here, and some case studies of assets that have participated in these services is available here.

Tenders are currently issued on a biannual basis, and information is available directly via the website, however participants are required to register onto the PicloFlex platform in order to pre-qualify and place bids for specific services and zones.

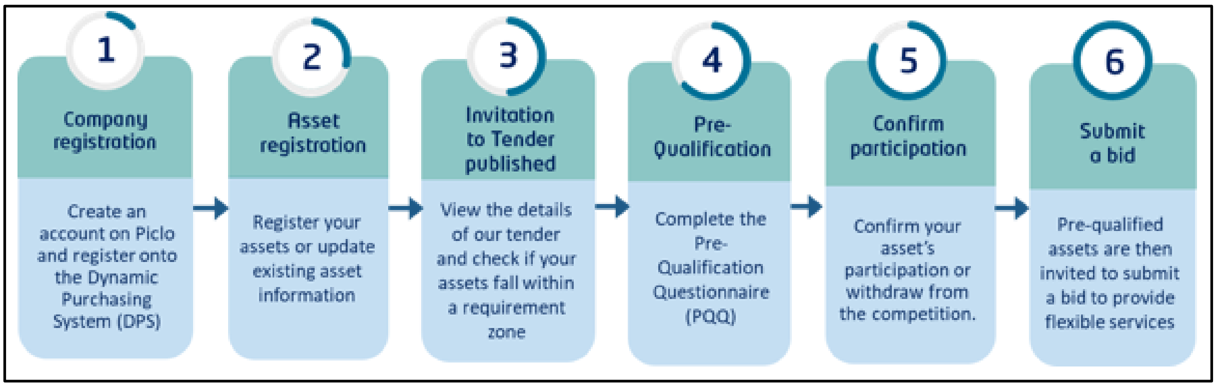


Figure 8-2 How to take part

All DNO's current use a 'standard flexibility agreement' that has been developed through the Energy Network Association Open Networks Project, and we also all use the Common Evaluation Methodology (CEM) and tool to evaluate bids against the counterfactual network solution.

Lots of further information including our full procurement process, decision making process, cost calculator tool, post code checker and general guides to flexibility are available on our website here, and access to our full service requirements for each tender is available using half-hourly data on our Data Portal here.

8.3 Flexibility Map for Bacup

The flexibility map for Bacup is shown in Figure 8-3. At this moment in time for the spring 2023 tender, there are no requirements for flexibility. However, as the network develops and more LCT's connect to the network, this could potentially change.

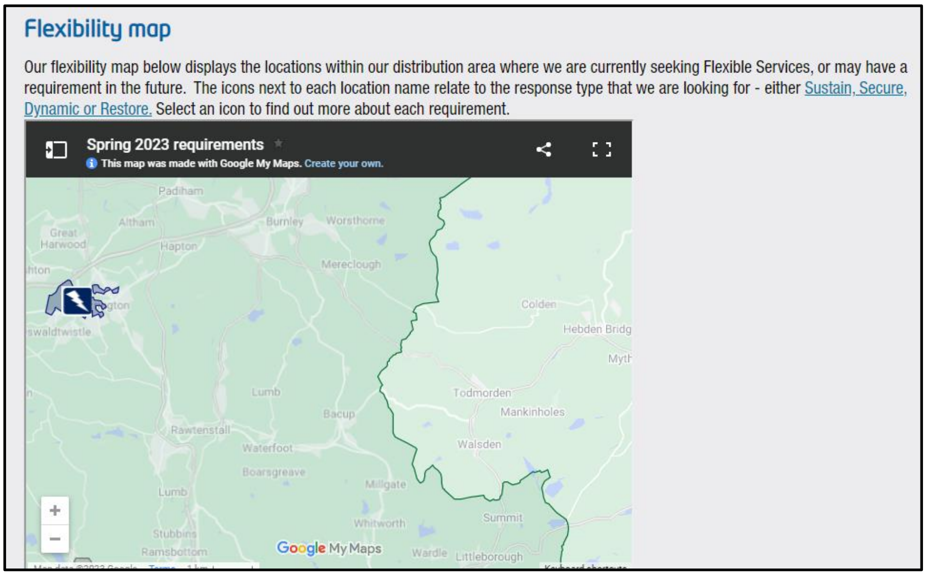


Figure 8-3 Bacup Flexibility Map

9 Connecting onto the network

In order to connect onto the distribution network, unless it is a domestic installation of an LCT such as a heat pump or solar panels under 3.68kW or 16A per phase, customers are required to apply directly to the DNO so that we can study the network to ensure a safe provision of supply. There are a number of different applications available, shown below, which have different costs and timescales associated to them.

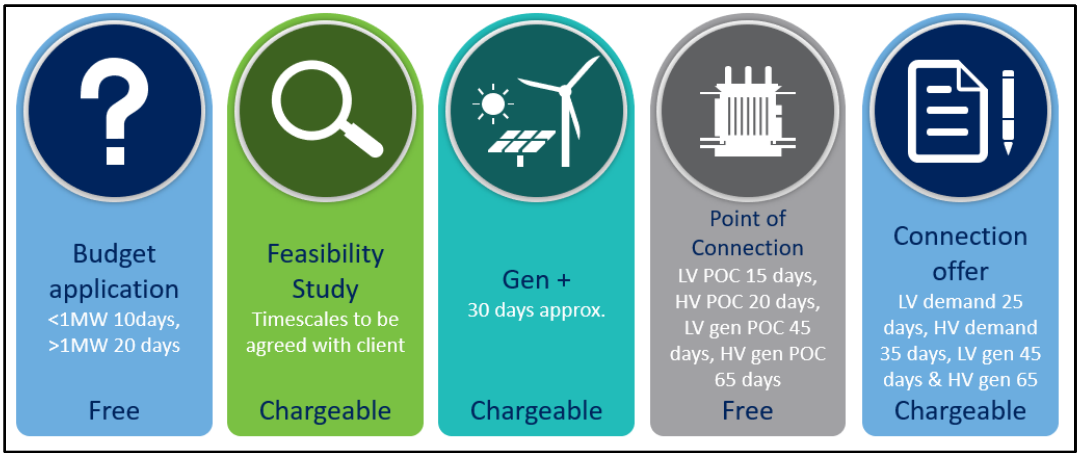


Figure 9-1 Connection Options

10 Charging review

From the 1st April 2023, a new charging regime has been implemented for connecting onto the distribution network following a Significant Code Review looking at Access and Forward Look Charges.

This review has reduced the cost of connecting onto the network by socialising reinforcement costs which will now be recovered through DUoS charges, that form the standing charge element of customers' bills. This applies when the network has insufficient capacity to be able to accommodate the connecting customers capacity. A summary of these changes is shown in Figure 10-1:

	Extension assets	Reinforcement assets at connection voltage	Reinforcement assets at connection voltage +1
Current arrangements	Connecting customer pays 100%	Connecting customer pays a proportion of the reinforcement costs	Connecting customer pays a proportion of the reinforcement costs
New arrangements (Demand)	Connecting customer pays 100%	Fully funded by the DNO via DUoS	Fully funded by the DNO via DUoS
New arrangements (Generation)	Connecting customer pays 100%	Connecting customer pays a proportion of the reinforcement costs	Fully funded by the DNO via DUoS

Figure 10-1 Reinforcement Costs

11 Flexible connections

Reinforcement works can be quite time consuming to complete if significant network upgrades are required, and so flexible connections are available which offer constrained network access either while reinforcement work is completed, or to avoid reinforcement charges.

We currently offer the following types of flexible connection:

- System Normal Connection - A system normal connection is disconnected or constrained when there is a First Circuit Outage affecting the circuit dedicated to supplying the customer or the local Distribution System. This connection could be managed either remotely or via an intertripping scheme.
- Export Limited Connection - A connection where the installed generation equipment has a greater export capability than that which has been agreed to be exported onto the Electricity North West distribution system.

We are in the process of implementing our new Network Management System which will allow us to offer the following additional flexible connection options:

- Timed Connection - A connection arrangement where connection capacity is subject to restrictions within specific time periods.
- Import Limited Connection - A connection where the installed equipment has a greater import capability than that which has been agreed to be imported from the Electricity North West distribution system.
- Active Network Management - Use of control systems to modify import and/or export in line with previous agreed limits.

In order to progress with a flexible connection, this will need to be indicated this on your application form. You can also include further details of your requirements within the ‘additional information’ section of your application, and our planning teams will be in touch to discuss this with you. We already offer flexible connections as standard for all generation connections greater than 200kVA.

If you accept a flexible connection offer, your asset may be constrained up to an agreed limit under certain conditions, ie when the network is operating ‘abnormally’. The conditions of the constraint and level of constraint will be set out in your offer letter.

To progress with an alternative connection offer, you will need to make sure you are able to control your asset in response to the constraint conditions within your offer.

12 Information and support

To help our customers with their applications, we have a dedicated Pre Application Customer Engagement (PACE) team, that can provide support on the type of application required, understanding your requirements and providing advice on what and how to connect onto the network.

There is also a wealth of information published to give an indication of available capacity and existing network arrangements available on our website and data portal. These data sets are available for different voltages to allow you to understand the region of the network you are wanting to connect onto.

Low Voltage – Network Asset Viewer

High Voltage – network capacity map and headroom data

Extra High Voltage – Heat map that shows available headroom.