Net Zero Terrace

Alpha Phase

Work Package 4: DNO/DSO Integration

March 2024

Electricity North West

Version

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Approval

Name	Role	Signature & date

Executive Summary

Community energy groups play an important role in enabling consumers to discover how they can participate in accelerating net zero. The reduction in carbon emissions and cost savings should benefit every consumer equally including those from fuel poor backgrounds. The Net Zero Terrace (NZT) project aims to harness communities of terraced streets to decarbonise together by creating a Smart Local Energy System (SLES), from which each consumer can play an active role in.

As part of the NZT SLES, a combination of individual Low Carbon Technology (LCT) assets will be installed in households and shared LCTs in the community. The main aspects of this will be a closed loop Ground Source Heat Pump (GSHP) installed in each house and a shared Photo-Voltaic (PV) array across the roof connected direct into the Distribution Network Operator (DNO) network.

Historically, the DNO network assets were installed to enable outward power flows to consumers with minimal active participation. In the push towards net zero, this has recently changed with domestic customers on the Low Voltage (LV) network installing their own assets and participating in external electricity markets and peer to peer trading. It is anticipated that an innovative solution such as NZT could play a large role for terraced street communities to connect not only on the Electricity North West Limited (ENWL) network, but all other DNO networks across the UK.

The challenge of this is how do DNOs enable such a solution whilst managing high levels of connection studies and reinforcement schemes. The SLES involves installing significant levels of generation and demand risking network constraints such as voltage, thermal and fault level. In the discovery phase, the trial area in Bacup included an LV feeder with a connection of 84 homes each with a 1.6kWe GSHP and over 100kW of shared PV arrays across 7 terraced rows. This was before any further community assets where added. The level of penetration of LCTs requires DNOs to think more strategically in how these connections could be managed.

The aim of this report is to establish the integration process for installing the NZT SLES into the network by considering more efficient and innovative methods. This starts from the initial task of a community energy group finding an 'area of interest' on the network using a Geographical Information System (GIS) to gathering initial network and household data. The data on the GIS map will shortlist areas of the network where the solution is most likely able to be deployed without triggering any reinforcement.

The community energy group will then pass the data to the DNO, who will process the data and commence a connection study. The outcome of the study will see different options for the solution to be deployed including a connection with no restrictions or reinforcement, a standard reinforcement solution and an innovative smart solution, which involves the installation of a LV Active Network Management (ANM) system.

The NZT SLES solution will therefore be able to connect onto the network in a faster more efficient way without reinforcement being a barrier to uptake.

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Acronyms and Abbreviations

ADMD	After Diversity Maximum Demand
ANM	Active Network Management
BAU	Business As Usual
CAD	Consumer Access Device
CB	Circuit Breaker
CEMS	Community Energy Management System
DNO	Distribution Network Operator
DUoS	Distribution Use of System
ENA ER	Energy Networks Association – Engineering Recommendation
ENWL	Electricity North West Limited
EPD	Electricity Policy Document
EVCP	Electric Vehicle Charge Points
GIS	Geographical Information System
GSHP	Ground Source Heat Pump
GSOP	Guaranteed Standards of Performance
HEMS	Home Energy Management System
HP	Heat Pump
KW	Kilowatts
KWe	Kilowatts Electric
LCT	Low Carbon Technology
LSOA	Lower Layer Super Output Layer
LV	Low Voltage
MAD	Minimum Average Demand
NMS	Network Management System
NZT	Net Zero Terrace
OFLTC	Off Load Tap Changer
OLTC	On Load Tap Changer
PV	Photo-Voltaic
SIF	Strategic Innovation Fund
SLES	Smart Local Energy System
THD	Total Harmonic Voltage Distortion

1 Introduction

This report covers the requirements for **Work Package 4 – Deliverable 4 (review of the DNO process with recommendations for how to integrate NZT into the network)** in the Alpha phase of the NZT Strategic Innovation Fund (SIF) project.

The NZT solution enables communities of terraced houses to transition to net zero by retrofitting households to a high energy efficient standard and the installation of LCTs. The LCT assets are a combination of:

- **Behind the meter GSHPs with thermal storage**
- **Community owned PV connected direct into the LV network**
- **Other community owned assets such as Electrical Storage and Electric Vehicle Charge Points (EVCPs)**

The solution is scalable and can be thought of as a community microgrid with each LV feeder having its own microgrid or a SLES.

The SLES will be controlled by a central community energy management system (CEMS) working in conjunction with each household through its own household energy management system (HEMS). The HEMS focuses on optimisation to ensure a level of heat comfort is maintained inside the house and enables consumers to save on bills by matching supply and demand with the community generation. The CEMS monitors the operation of each HEMS and assesses any excess consumption that could be sold into the external electricity markets.

During the Discovery phase an LV connection study was carried out on a trial area in Bacup. The impact of over 100 terraced houses across three LV feeders supplied by a single distribution substation were assessed with the additional load of 1.6kWe individual house GSHPs and shared rooftop PV arrays. There were 10 arrays in total with each array having an average rating of 18kW. At the Discovery stage there was no assessment for other technologies such as battery storage or EVCPs.

The findings from the Discovery phase concluded that a standard LV network reinforcement solution is a highly likely outcome of installing the NZT SLES. The LV network was not designed to accommodate such large levels of LCTs. There were issues both from a thermal and voltage point of view.

The challenges therefore can be summarised as:

- **Demand associated voltage drop and thermal constraints due to import power flows**
- **Generation associated voltage rise and thermal constraints due to export power flows**

The two challenge points above result in delayed deployment of the NZT SLES due to expensive and time-consuming reinforcement. The costs of which are recovered through all network consumers through Distribution Use of System (DUOS) charges.

If the NZT SLES approach is a viable community solution, then looking ahead into a business as usual (BAU) phase, we would expect multiple applications for clusters of NZT SLESs across the DNO LV networks in locations where terrace properties dominate. The challenge for DNOs is how to facilitate this. The NZT SLES solution needs to be deployed within a reasonable time without large backlogs of applications, connection studies and reinforcement schemes.

This report will detail the findings and options for a smart innovative solution to deploy the NZT SLES onto the ENWL and other DNO's networks.

2 Existing DNO processes

This section describes the current processes for managing connection applications through channelling based on the type, volume and size of LCT to be connected to the distribution network. The GB distribution networks operators have come together and working under the banner of Energy Networks Association (ENA) have collectively defined common connection applications template and processes, which are referenced below.

2.1 Demand LCT – Single Premises

Should an application be received for connection of a single demand LCT, i.e. a GSHP or an EVCP onto the LV network, the application is straight forward and can be managed under the connect and notify approach.

This is shown in the ENA combined EVCP/Heat Pump (HP) process flow chart on the link below with the main consideration being the condition of the customer's cut out and installed capacity for HPs being below 32 Amps per phase - Electric Vehicle Charge Point and Heat Pump Combined Installation Process Flow Chart v1.3.pdf (energynetworks.org).

2.2 Demand LCT- Multiple Premises

If an EV and / or HP is to be installed in multiple premises in one application, the after diversity maximum demand (ADMD) of the nominated low carbon technology needs to be confirmed.

ENA Engineering Recommendation (ER) P5 gives typical load profiles and presents a suitable method for calculating the ADMD. This calculation has been built into the LV AFFIRM[1] calculator spreadsheet.

For HPs a flicker assessment under **BS EN 61000-3-11** and a harmonic assessment under **BS EN 61000-3-12** should be carried out if the amps per phase are above 16 Amps but less than 75 Amps. Any HP connection above 75 Amps will need a study under **ENA ER P28 and ENA ER G5.**

2.3 Generation LCTs (including Domestic Storage)

When assessing generation on the LV network when considering either a single or multiple premises application, 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. The effect of the generation can then be assessed at the time of minimum demand.

- **The MAD values are covered in ENWL Electricity Policy Document (EPD) 283 – LV Design Manual[2].**
- **All generation below 16A per phase will need to be covered under ENA ER G98**
  ENA_EREC_template_v1.0 (energynetworks.org)
- **All generation above 16A per phase will need to be covered under ENA ER G99**
  ENA_EREC_template_v1.0 (energynetworks.org)

Further information on connection generation LCTs can be found on the ENA website: Connecting commercial generation to the electricity networks – Energy Networks Association (ENA).

[1] Used by the ENWL connections team to assess suitability of the connection against the network thermal and voltage constraints.

[2] This is currently being added into the policy document and will be available imminently in an updated version.

2.4 NZT SLES application considerations

The most immediate consideration when reviewing the connection of the NZT SLES is that the connection will be for more than one house. Hence the connect and notify approach for demand applications will be invalid. Likewise for the generation, any PV array will be over 16A and therefore would need a G99 study. Hence a full connection study for each application would be required.

To carry out a connection study using the LV AFFIRM calculator the LV feeder details including cable data and types of houses must be obtained and entered manually into the spreadsheet. The drawback of this is that it is a time consuming and detailed approach.

Managing and processing a small number of NZT SLES type applications per quarter would not have a significant impact on the network business. For example we do not foresee there will be any negative consequences of the DNO providing the connection quotes within the time periods prescribed by the Guaranteed Standards of Performance (GSoP) – Ofgem Connections GSoP. For a multiple property LV connection that is for example above four units, under GSoP the quote for a demand scheme must be provided within 25 working days and for a generation scheme within 45 working days.

However, if the NZT SLES solution became the norm for delivering net zero for terrace houses the networks business would expect to see tens of applications per quarter that could overwhelm the connections process and be a blocker to the net zero transition. Therefore, there is a need to find an efficient way to process all the applications and deliver the necessary reinforcements.

Simplifying and speeding up the connection process and adopting standard solutions will reduce the costs to serve. This will be important to avoid the networks being a blocker to community-based change. Where possible it will be beneficial to avoid reinforcement to give customers better value for money. However, deferring reinforcement may not always be the most efficient solution. The most cost-effective benefit in the long term could be to provide a solution which will last for a long time utilising a 'touch it once approach'.

The next sections of this report describe the end-to-end process for a more efficient way to deploy a NZT SLES into the DNO systems and processes.

3 Proposed NZT SLES integration process

3.1 Step 1: Identification of network areas to deploy NZT SLES

This step identifies at a high level if there are any issues on the DNO network where the solution is planned to be deployed. It is an initial data gathering journey which can be carried out by third parties such as community energy groups who are interested in deploying the NZT solution for their neighbourhoods after carrying out customer engagement.

To enable this phase, a Geographical Information System (GIS) map has been developed to triage areas of the network. A map was created using open-source data from OpenStreetMap and added into QGIS. On top of this a layer was added indicating the dwelling types by Lower Layer Super Output (LSOA) areas from the 2021 census[3]. Filtered from this are LSOA areas with more than 80% terraced houses. On top of this are vector data polygons indicating areas served by an ENWL distribution substation.

[3] LSOA 2021 Census Data

Figure 3-1: Information layers on GIS map for identification on potential NZT SLES locations

Voltage considerations

The nominal voltage of distribution transformers is 433/250 Volts (commonly written as V). The typical tap changer arrangement is an off-load tap changer (OFLTC) with 5 positions, 2 x 2.5% above and 2 x 2.5% below nominal. The steady state voltage of distribution substations therefore on the ENWL network sit above 240V. Adding large scale PV arrays onto the LV network has the potential to easily breach the 253V statutory limit (10% over 230V). The OFLTC position could be reduced but even this may not reduce the voltage enough to enable the penetration of large-scale PV arrays. For problem areas of the network such as the Bacup trial area, the tap changer was modelled at position number 1 but still the statutory limit was exceeded. Also, an OFLTC would not be applicable for use in a real time control system.

There are certain distribution substations within the ENWL network that have had their transformers upgraded to include an on-load tap changer (OLTC). This has been done as part of the 'Smart Street' innovation project[4] which aims to conservatively reduce the voltage on customers properties at peak times to reduce their bills without them noticing an effect.

With an OLTC the voltage can be reduced further than those capable with an OFLTC along with being able to be integrated into a real time control system. Hence, a layer was added into the GIS model to indicate those substations that have an OLTC. It is worth noting that substations that have had an OLTC installed will have also had a Weezap installed. A Weezap is an LV Circuit Breaker (CB) with reclosing capabilities that have been installed onto Smart Street LV ways (note this is not every way on a Smart St substation). The Weezap has additional capability of monitoring voltage, current, real and reactive power (commonly written as V,I,P,Q) data across the way. These values indicate the magnitude and direction of demand or generation on the LV feeder.

On substations that have not had an OLTC fitted, or for substations with an OLTC that have LV ways not covered by a Weezap, we can rely on for further LV monitoring via Pre-Sense units, which have been rolled out onto the LV ways of distribution substations post Covid. The Pre-Sense unit consists of a voltage clamp and a Rogowski coil, which wraps around each LV way to measure V,I,P,Q data which measures at 1 second and averages up to a granularity of 10 minutes. At the time of writing this report, there have been approximately 5,000 out of 33,000 distribution substations that have been fitted with LV Pre-Sense monitoring equipment.

The data from both the Weezap and Pre-Sense can then be sent via a mobile network to a cloud server for analysis to be used for planning purposes and enable ENWL to have visibility on the LV network.

From a voltage perspective, the Weezap and Pre-Sense can be used to observe the profile of the voltage over time at the substation. Hence, if for example the voltage went above 240V within a year period this could be filtered off the GIS map. For the purposes of other DNOs they will have different equipment available for monitoring their LV network assets that they would need to integrate into the solution.

If a distribution substation has no monitoring fitted, then the next best solution would be to look at smart meter data within a close boundary of the substation. The voltage data would be available

[4] ENWL Smart St Innovation Project

provided the consumer was on half hourly metering. As voltage is an anonymised data and consumer activity cannot be gauged, this data is available for the DNO in half hourly periods for 90 days. For external parties the consumer would have to consent to having their voltage data taken over a Consumer Access Device (CAD). An option for NZT is by using the fairer warmth app which potential customers sign up to use. A level of customer engagement would be required for this option.

Thermal considerations

Unfortunately, there is yet no visibility or forecasts of constraints on LV feeders. The available data is currently only limited to substations only. A dataset of forecasted capacity on substations up to 2050 will be included. The 2050 value would not be used, but a more sensible approach taking up to the end of the following regulatory period (RIIO-ED3) in financial year ending March 2033.

Monitoring Requirements

If the number of households with an LCT on a LV feeder exceeds 10%, ENWL will install monitoring equipment if it is not there already. This is useful information for the DNO to have as a NZT SLES could easily push the penetration of LCTs over 10%. A data set has been added to the GIS map which indicates the number of LCTs on each LV feeder. This is compared to the number of houses on the feeder and it will flag up to the DNO to install the necessary monitoring equipment if needed.

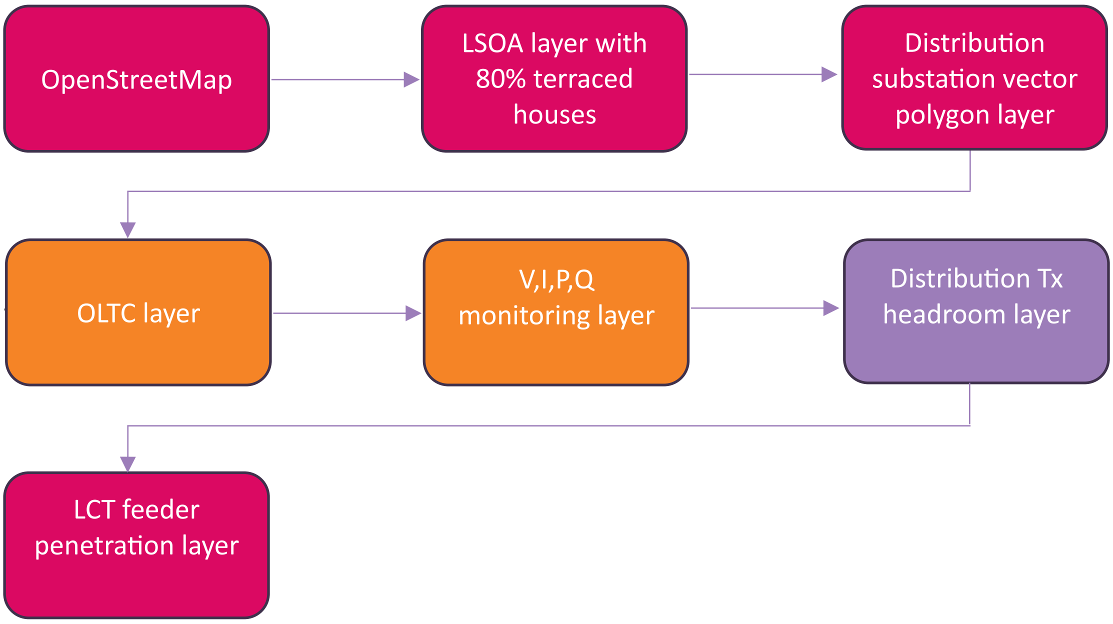

Figure 3-2: Information for identifying network and general characteristics in NZT SLES locations

There are four outcomes from this step:

- **Outcome 1 – Visibility of the network, voltage ok and thermal ok**
- **Outcome 2 – Visibility of the network, voltage not ok and thermal ok**
- **Outcome 3 – Visibility of the network, voltage not ok and thermal not ok**
- **Outcome 4 – No visibility of the network**

The outcome from this step will enable the third party such as the community energy group to determine whether there are any high-level network issues before submitting an application to the DNO. **The full flow chart detailing the first step is shown below in figure 4-3.**

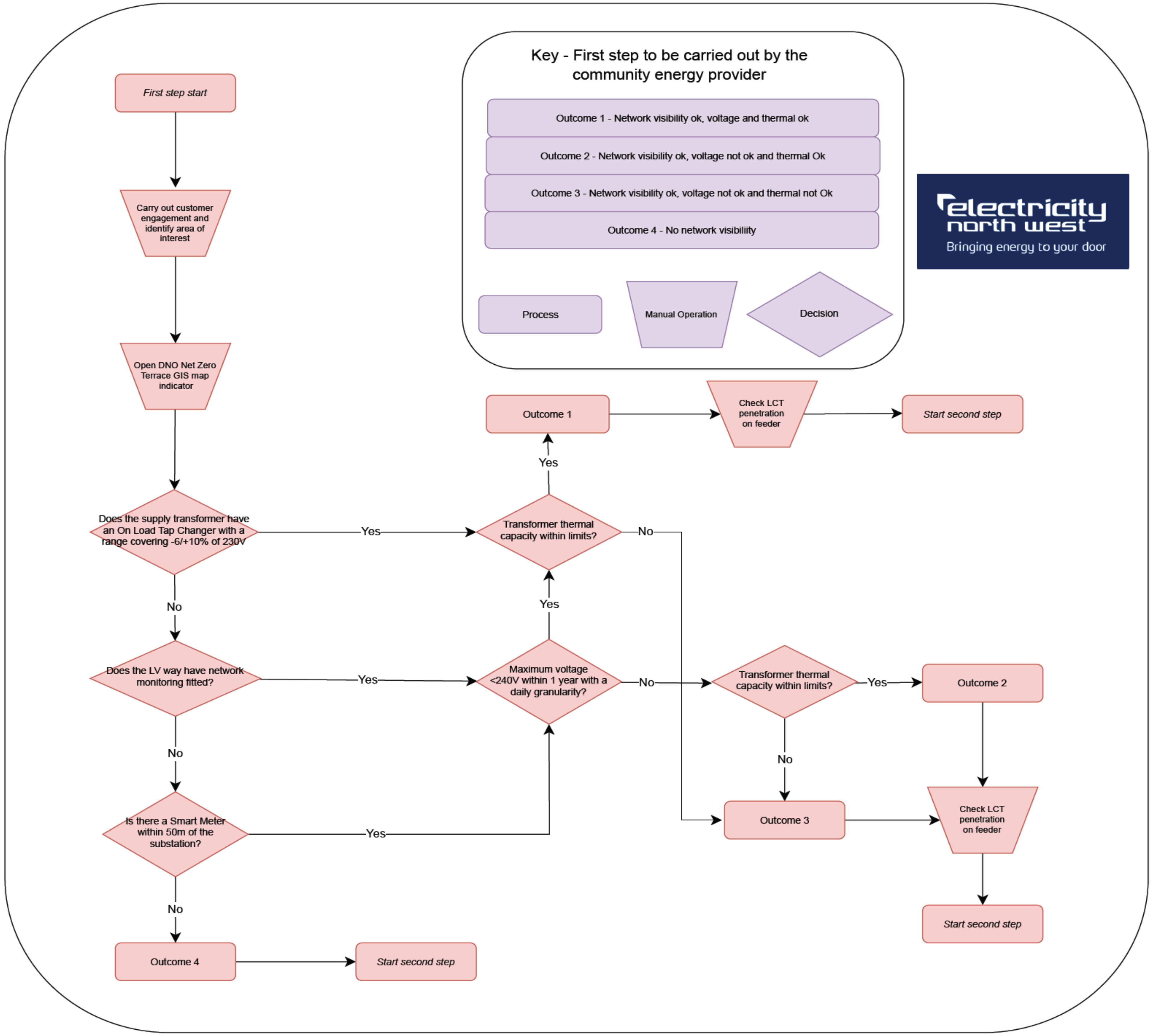

Figure 3-3: Flowchart describing the first step process

3.2 Step 2: Gathering further information on DNO assets serving customers

This step looks in more detail at the area of interest that has been identified at the first step. This could be completed again by a third party such as a community energy provider who should then have enough information to aid the DNO to process the connection request.

Initial house checks

The first half of the second step follows the existing connect and notify process whereby each house in the proposed NZT SLES will need to be investigated to check the condition of the service cutout. This could include any exposed cable or noises coming from the meter. A damaged or obsolete cutout would need to be repaired or any looped services would need to be unlooped before any NZT SLES could be installed. Retaining a looped service is satisfactory if there is only one LCT on those sections of loop. Even in this case the single LCT would only be allowed if there are no more than 4 cut outs on the loop assuming each house was not electrically heated and each cut out rating was 100A.

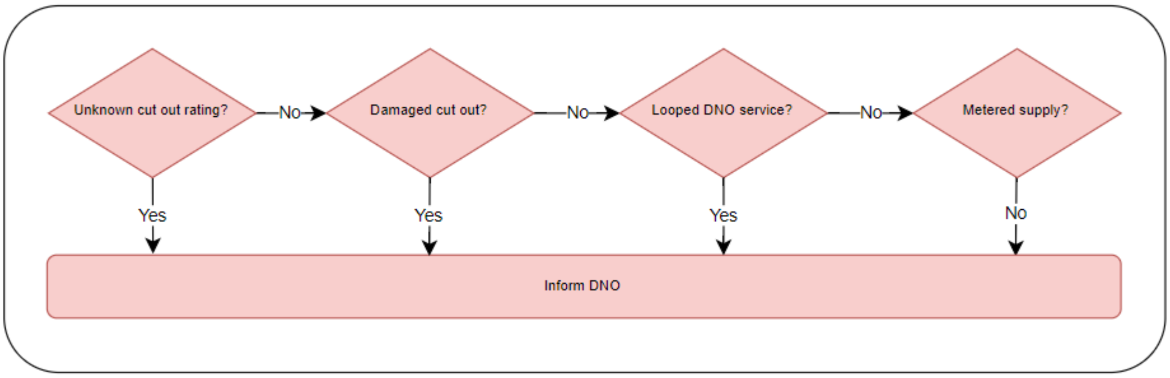

Figure 3-4: Gathering information on the existing DNO network assets

Initial works will be required to mitigate either the damaged/unknown cut out or the looped supply should this be found to be an issue.

NZT SLES components - demand

The demand components for a NZT SLES include the heat pumps, any demand associated with electrical storage and EVCPs.

The maximum demand for a whole current metered single-phase connection is 20kW. Hence any household demand with the additional load of a LCT cannot exceed this value without installing a three-phase supply.

For a single GSHP if the demand exceeds 75A then an ENA ER G5 harmonic study and ENA ER P28 flicker study will need to be undertaken. For the purposes of a NZT SLES the aggregated effect of all the GSHPs together will be assessed.

The ENA ER G5 study must ensure that the Total Harmonic Distortion (THD) does not exceed planning limits. For a voltage less than 400V the planning limit is 5% of the fundamental frequency. A stage 1C study is applicable for aggregated connections greater than 75A at LV. The fault level at the Point of Common Coupling (PCC) will need to be provided by the DNO to enable this assessment. The background harmonic level can be assumed to be no higher than 75% of the planning level. The cumulative rated power of the GSHPs need to be determined. A permitted aggregated power can then be determined using G5 formulas.

If the cumulative demand from the GSHPs is less than 75A but greater than 32A, then the simple 1B study can be undertaken. The fault level at the PCC will be needed and this can be compared to a minimum fault level. The minimum value is assumed and can be found in G5 based on the equipment rated power.

Regarding flicker, ENA ER P28 gives the planning and compatibility level for an LV connection at 1 for short term and 0.8 for long term. The units for this are a measure of the visual severity of flicker derived from the time series output of a flicker-meter over a 10-minute period. A stage 2 assessment and if necessary, a stage 3 is needed if the aggregated connection is more than 75A. If the connection is less than 75A a simplified stage 1 study can be carried out which compares the maximum permissible source impedance declared by the manufacturer against the actual source impedance. The source impedance will need to be provided by the DNO.

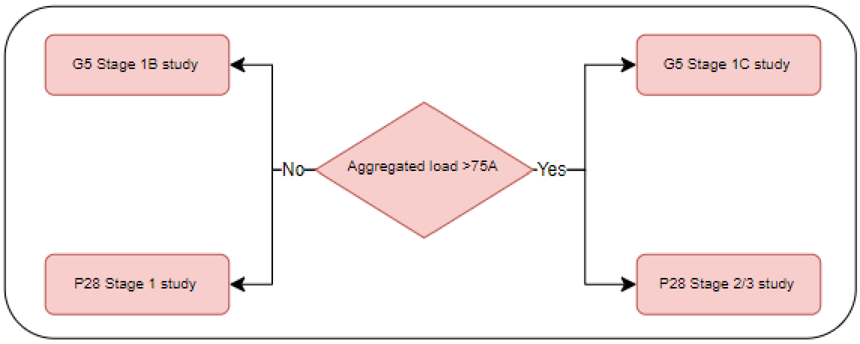

Figure 3-5: Process for assessing harmonics and flicker

It is anticipated that in the coming years as more LCTs are added onto the network, the harmonic/flicker effects will arise. If more than 10% of LCTs are added onto the network, then equipment must be installed to monitor these effects. There is an argument that if existing monitoring equipment is fitted then no study would be required as the DNO would then act upon any harmonic or flicker issue that has arisen post monitoring.

If the NZT SLES includes an EVCPs with vehicle to grid technology, then this component of the EVCPs must be assessed under generation.

<u>NZT SLES components – generation</u>

The main requirements for generation include compliance under either ENA ER G98 or ER G99. If the generation is less than 16A per phase this can be covered under G98. However, for the NZT SLES solution the generation will be covered under G99. All equipment must be type tested for compliance.

<u>Second Step Outcomes</u>

There are three outcomes from this step, however there may be a scenario when this stage would need to be reassessed. For example, if the initial house checks are not ok, this step will need to be repeated once mitigated to check for outcome 2 and 3.

- **Outcome 1 – Initial house checks not ok**
- **Outcome 2 – Harmonic or flicker study needed**
- **Outcome 3 – Connection study needed**

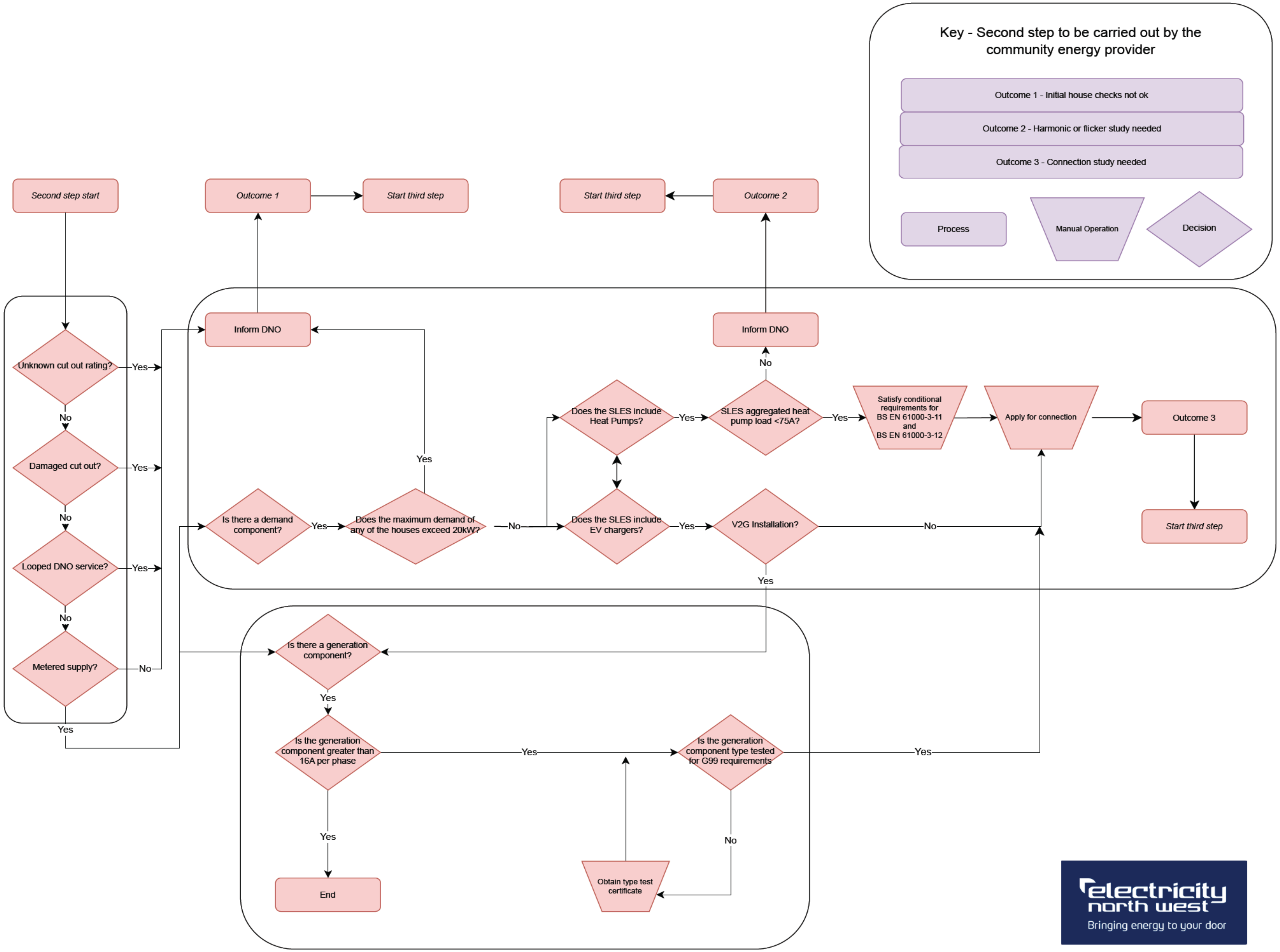

Figure 3-6: Figure 4 3: Flowchart describing the second step process

3.3 Step 3: DNO Connection study

By the third step, the DNO should have the information to process the connections application. The information could have been provided by a third party such as the community energy provider.

The full suite of information will include:

From first step

- **If the network of interest has an OLTC**
- **If the network of interest has LV monitoring equipment (V,I,P,Q)**
- **If the network of interest has a transformer with spare kVA capacity headroom**
- **If the network of interest has a yearly voltage profile at the substation <240V**
- **If the percentage of LCTs on the network of interest is over 10%**

From second step

- **If any of the houses in the network of interest have a problem with the cutout**
- **If any of the houses in the network of interest are on a looped service**
- **If a harmonic or flicker study needs carrying out**
- **If a connection study needs carrying out**

The DNO can then apply the information from the previous steps to work out the tasks they then need to carry out. This is shown in table 4-1.

Table 3-1: DNO tasks following the first and second step

		Second step outcomes (community energy provider)			
		Outcome 1 - Initial house checks not ok	Outcome 2 - Harmonic or flicker study needed	Outcome 3 - Connection study needed	
		Repair cutout or unloop service	Carry out G5 and P28 study (or provide fault level and impedance data to third party)		Third step tasks (DNO)
First step outcomes (community energy provider)	Outcome 1 - Network visibility ok, voltage and thermal ok	--	--	Perform load flow calculation	
	Outcome 2 - Network visibility ok, voltage not ok and thermal ok	--	--	Set OFLTC to 1 and perform load flow calculation	

	Outcome 3 - Network visibility ok, voltage not ok and thermal not ok	--	--	Perform load flow calculation and determine level of reinforcement	
	Outcome 4 - No network visibility	--	--	Install substation V,I,P,Q monitoring and perform load flow calculation	

The information gathered in the first step has narrowed down parts of the network where the risk of an issue in the connection study is lowered and the best chance to deploy the NZT SLES without any reinforcement is higher.

Rather than a manual calculation exercise, it is proposed to develop a solution to model a load flow of the LV feeder in question on a suitable network model. For ENWL this is being developed on the Network Management System (NMS) control system which has an LV model based on the GIS data of the network along with associated asset data.

There is a load flow function built into the software which soon will be capable of measuring the steady state power flow conditions with the ability to add additional LCT loads and generation from the NZT SLES. It is likely that the other GB DNOs would have different means of performing load flows depending on which software application they use to model their networks. A third party could also carry out this task by taking a digital twin of the DNOs network along with asset data and modelling the additional loads and generation.

The outcome of the load flow will determine if there any voltage or thermal constraints on the LV feeder. This will then determine the level of reinforcement that would be required.

Table 3-2: DNO tasks based on load flow and reinforcement level

		Load flow result		
		Load flow ok	Load flow not ok	
Reinforcement level (determined by DNO)	None	Install substation monitoring and SLES with no restriction	--	**DNO tasks**
	OLTC only	--	Install OLTC only and repeat load flow	

	Light (<50m of LV cable)	--	Operating restriction OR install monitoring equipment, SLES and **smart** solution	
	Medium (<100m of LV cable)	--	Operating restriction OR install monitoring equipment, SLES and **smart** solution	
	Heavy (>100m of LV cable with new HV substation)	--	Operating restriction OR install monitoring equipment, SLES and **standard** solution	

If there is a voltage or thermal issue the NZT SLES could only be installed via an operational restriction (fixed or dynamic) or a smart innovative solution.

After the load flow stage, it will now be clear whether the NZT SLES can be installed with a traditional standard reinforcement solution or a smart innovative solution.

The smart innovative solution involving the deferral of reinforcement will be discussed in further detail under the options section of this report. If a smart innovative solution has been installed, this has indicated that there is a network issue. By implementing this option, the DNO can ensure that this solution connects onto the network and provides benefit to the customers whilst enabling the uptake of LCTs.

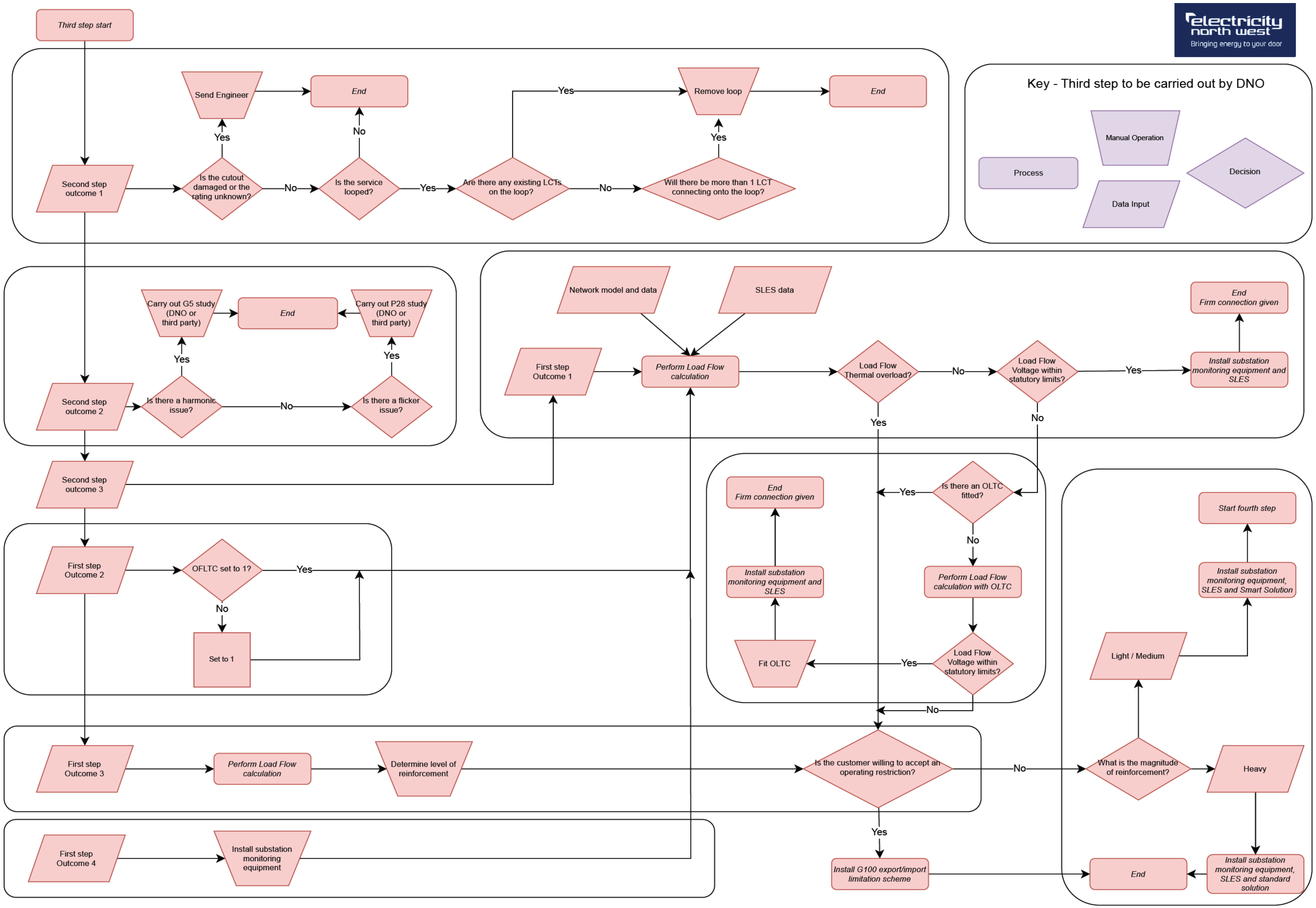

Figure 3-7: Flowchart describing the third step process

4.3.1 Proposed NZT SLES Architecture

The proposed architecture for the NZT SLES has been designed by Buro Happold, this is shown below in figure 4-8.

The LCT assets in the architecture are a combination of:

- **Behind the meter GSHPs with thermal storage**
- **Community owned PV connected direct into the LV network**
- **Other community owned assets such as Electrical Storage and Electric Vehicle Charge Points (EVCPs)**

The NZT SLES will be controlled by a CEMS working in conjunction with each household through its own HEMS. The HEMS focuses on optimisation to ensure a level of heat comfort is maintained inside the house and enables consumers to save on bills by matching supply and demand with the community generation. The CEMS monitors the operation of each HEMS and assesses any excess consumption that could be sold into the external electricity markets.

The architecture is essentially an individual LV microgrid contained within the LV way. The extent of LCT assets on the feeder associated with the solution will cause dynamic power flows on the LV network with the potential for constraints to occur. The steps taken from first to third will enable the solution to be installed without risking these constraints materialising and causing issues on the network thus risking continuity of supply to customers.

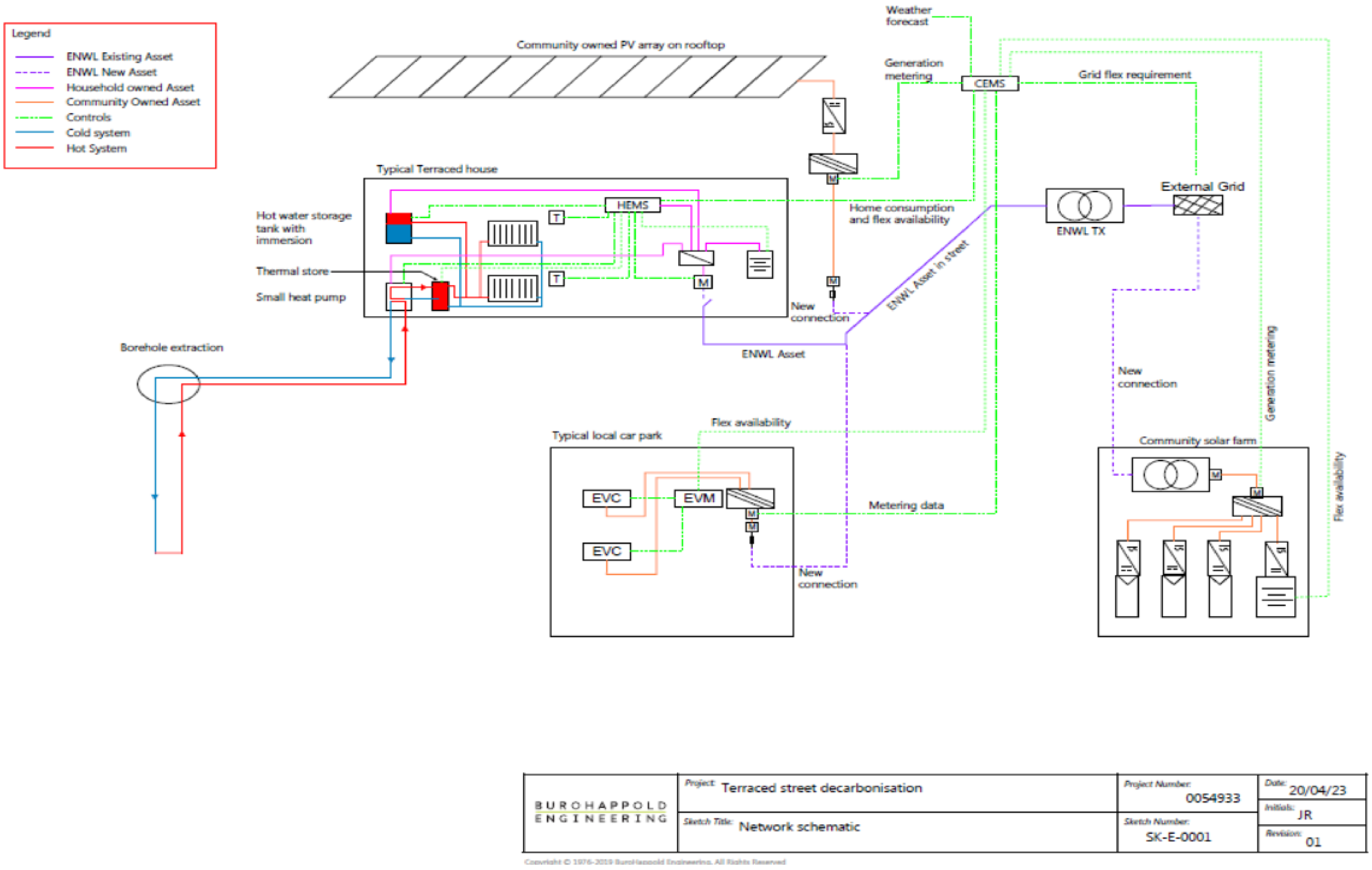

Figure 3-8: Architecture schematic of the NZT SLES

4.3.2 Options summary

The third step has identified the network requirements for installing the NZT SLES. The best-case option would be a non-curtailable connection which would permit the solution onto the network without any operating restrictions.

In cases where the voltage is outside statutory limits and where proven on the load flow that an OLTC can mitigate this, there will be reinforcement associated with an OLTC installation. This would be the second best-case option whereby a firm connection could still be given once the OLTC is installed.

If the network has exceeded its ratings based on connecting the LCT assets associated with the NZT SLES then there are two addition options to enable the solution: A standard reinforcement or a Smart Innovative option.

Option 1 – Non-curtailable Connection

Under option 1, the third step has found no network issues both from a thermal and voltage perspective. If the NZT SLES was installed on the network, the planners at the DNO can be confident that no issues would occur under intact or abnormal running conditions such as for a change in network topology.

The community energy provider would receive a non-curtailable connection agreement, and this will stay in place indefinitely without further study once signed.

Option 2 – Non-curtailable Connection associated with OLTC

It was found during the discovery phase that the most common network issue associated with the NZT SLES is the PV causing voltage rise above statutory limits. In this instance the LV voltage has exceeded 253V. The standard nominal voltage for an ENWL OFLTC transformer is 250V and can be tapped down to 237.5V. With the OLTC this can be reduced to 218.75V – see figure 4-9.

SWITCH POSITION	CONNECTION	TAPPINGS ON HV %	NO LOAD VOLTAGE (WHEN HV COSNTANT)			NO LOAD VOLTAGE (WHEN LV COSNTANT)	
			HV (V)	LV (V)	LV (%)	HV (V)	LV (V)
1	A-1	+14.286	11000	218.75	-12.5	12571.5	433
2	A-2	+11.111	11000	225	-10	12222.2	433
3	A-3	+8.108	11000	231.25	-7.5	11891.9	433
4	A-4	+5.263	11000	237.5	-5	11578.9	433
5	A-5	+2.564	11000	243.75	-2.5	11282.0	433
6	A-6	0.00	11000	250	0	11000.0	433
7	A-7	-2.439	11000	256.25	+2.5	10731.7	433
8	A-8	-4.762	11000	262.5	+5	10476.2	433
9	A-9	-6.977	11000	268.75	+7.5	10232.5	433

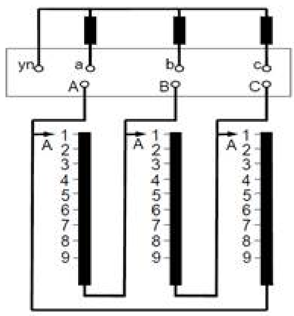

Figure 3-9: OLTC tap range

Therefore, option 2 can help mitigate one of the biggest issues with the NZT SLES solution – the PV voltage rise. This would enable the solution to connect without resorting to expensive reinforcement schemes. To enable this option, a new distribution transformer is required. The OLTC cannot be retrofitted onto existing transformers.

Option 3 – Non-curtailable Connection associated with Standard Reinforcement Solution

Option 3 involves reinforcement consisting of new LV cables, transformer uprating and new substations associated with HV work such as loop ins. This would be applicable if the first pass stage has identified an area of the network that has a transformer forecast to exceed its thermal rating or if the third pass stage has failed its load flow despite fitting any applicable OLTC.

Depending on the size of the NZT SLES and the network assets, the level of reinforcement would have certain depths from a light level through to a heavy level. The heavier the reinforcement the more likely it is that the magnitude of the solution is bigger and the number of assets connecting is higher.

In an area where the solution has a high number of assets to be installed, a few assumptions can be made. Firstly, the LV feeder is in an area that is populated and will continue to be an area in favour of having LCTs installed. The community energy group in a heavy area will have successfully engaged a large group of customers, hence it is feasible to estimate that further customers in the future could be added onto the solution which adds in a risk of further uptake.

The risk of further uptake enables the DNO to take a view on how long a smart solution would work for. Since a smart solution defers reinforcement, any high risk of further uptake renders a smart solution less feasible and would in the shorter term require the reinforcement to be carried out anyway.

Table 3-3: Reinforcement Depths

Reinforcement Depth	Illustrative Reinforcement Works	Number of Assets	Risk of further uptake
Light	<50m of new LV cable	Low	Low
Medium	<100m of new LV cable	Medium	Medium
Heavy	>100m of new LV cable, new distribution substation and associated HV works	High	High

The utilisation of a smart solution thus can be predicted in years once installed, how long it would last for before a standard reinforcement solution would be needed. This information is needed for the CBA metrics when assessing the value of paying for a smart solution versus paying for reinforcement assets. In the case of a heavy uptake the value is lower for a smart solution compared to the light uptake where the value is higher.

Table 3-4: Number of years before a standard reinforcement solution is needed

Risk of further uptake	Utilisation of smart solution (years)
Light	15
Medium	10
Heavy	5

The disadvantage of this option is the cost of reinforcement and associated delay in connection time. However, the advantage is a robust network once reinforcement is complete. The CBA will determine the most efficient solution between options 3 and 4 depending on how long the network can last on a deferred reinforcement solution.

Option 4 – Smart Innovative Solution

A LV Automatic Network Management (ANM) system will be added into the architecture of the solution. Such a solution will monitor the network and dispatch or constrain local assets within the NZT SLES accordingly to manage the health of the network.

The ANM system will be added into the CEMS as an additional function. The CEMS will take V,I,P,Q input data from the feeding substation ways via Pre-Sense LV monitoring and also take in the smart meter data from each asset within the NZT SLES.

The ANM will monitor the LV network and if any export constraint occurs due to voltage or thermal issues it will curtail the PV arrays and / or electrical storage on a Merit Order System until the constraint is alleviated.

To provide real time constraint monitoring, the granularity of the pre-sense data will need to be reduced from the current 10-minute average to real time. A reduction in granularity of smart meter data will also need to be explored. This has been confirmed by one of the other project partners that smart meter data is available a granularity of up to 10 seconds and can be accessed in the cloud via a consumer access device (CAD).

The ANM supplier is an external provider as there is no existing LV ANM function in the ENWL NMS control system. The ANM provider will need a digital twin of the DNO network associated with asset data to model the power flows in real time to determine if a constraint will occur.

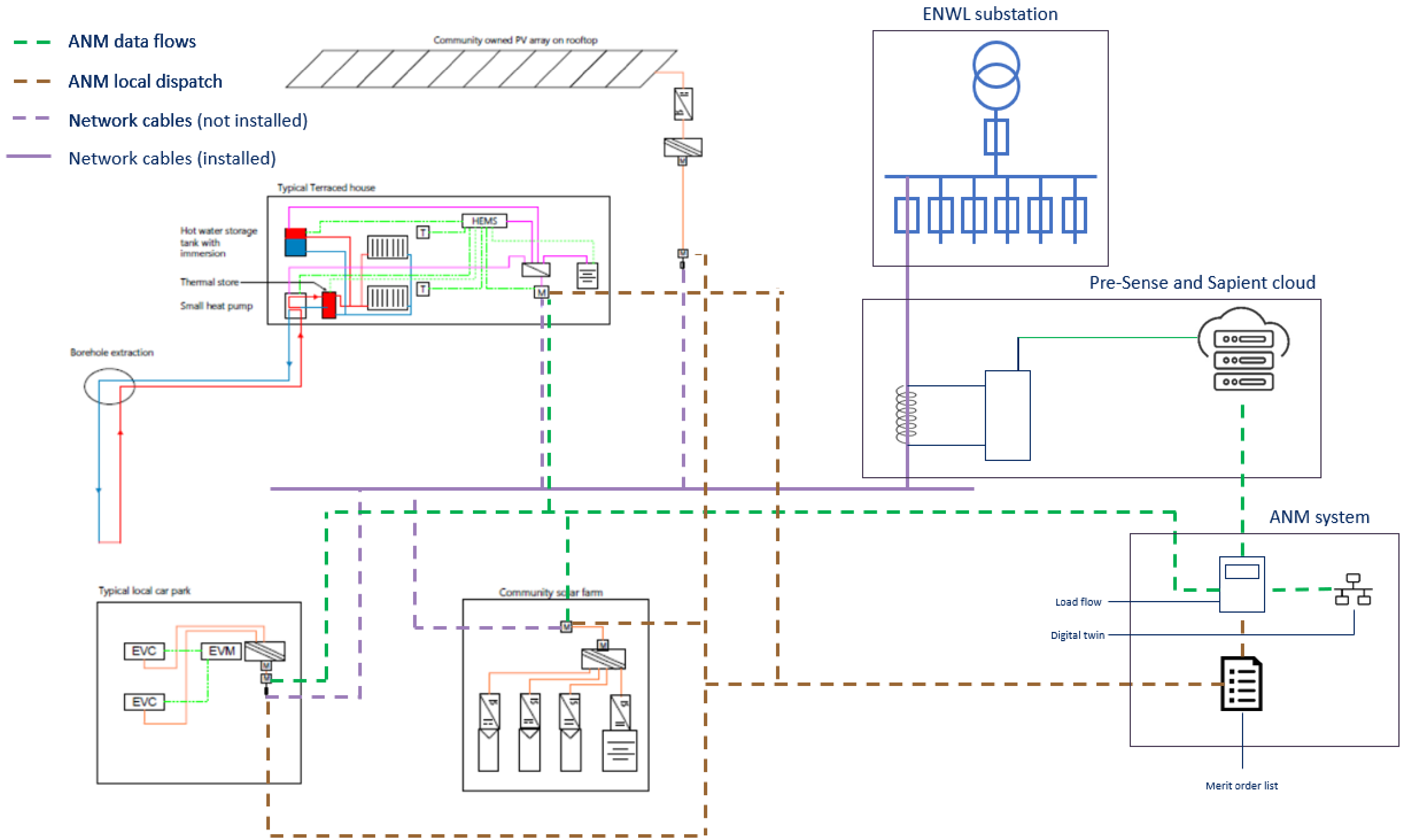

Figure 3-10: NZT SLES with the additional option 4 architecture

The Export assets will have the following operating modes.

- **No export into network**
- **Aggregated to row / street (export matched to import of row/street)**
- **Full export into network**

The aggregated to row / street option will effectively cancel out any export power flows into the network thereby not risking a network constraint. For an asset to fully export into the network the sequence of events will begin with a check to see if any network constraints are present. If not the ANM will dispatch the asset accordingly.

Import Constraint.

Similarly, the ANM will monitor the LV network and if any import constraint occurs due to voltage or thermal issues it will reduce the output of the heat pumps or electric vehicle charge points. This will be dependent on if the HEMS allows for a reduction in demand, for example if the heat pump is in hot water mode only or if a lower set points in space heating can be met by ramping down the pump.

An important point about the real time control is that it would need to have a fail safe in the event of communications failure. In this instance the NZT SLES would default to a 'no export into network' hierarchy to reduce the impact of any power flows into the network.

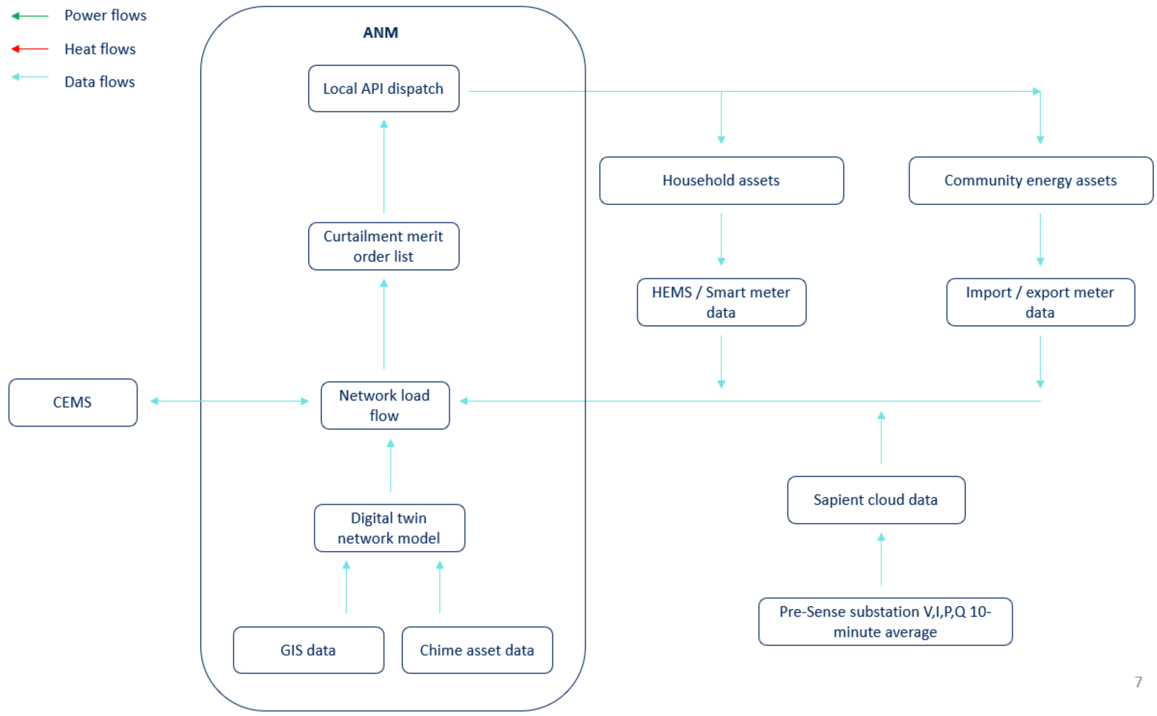

Figure 3-11: Data flows for ANM model

3.4 Step 4: LV monitoring following installation of option 4

The final step is the continuous monitoring of the impact of installing the smart solution.

If the level of constraints on the LV network is high, the efficiency of the smart solution will be reduced because the assets will keep getting curtailed. This takes away some of the benefit of the solution but also indicates to the DNO that reinforcement is required and ultimately is the best solution.

Each asset in the smart solution will have a curtailment index which will be decremented each time it gets curtailed. This will then place it more favourably in the merit order list should it be called up again to be curtailed in the future. The curtailment index along with determining the order of the list is also a limit which once exceeded gives the indication to the DNO that reinforcement is required. For other DNOs alternative method of the merit order list could be used such as the last in first out approach.

Following on from any curtailment index being exceeded, the DNO will carry out a traditional planning study to determine the lowest cost reinforcement option.

It is then anticipated in this case that the smart solution would no longer be needed and the NZT SLES assets would transition to a firm connection. To ensure that the smart solution is a long-term viable option, as stated before it will not be installed on any network area where heavy reinforcement is required.

This approach may change as the project enters Beta and into business as usual (BAU). It might be that even for areas that require a light and medium level of reinforcement, the curtailment index limits of NZT SLES assets are exceeded. In such an instance another method of determining the best case for either a standard or smart solution would need to be determined.

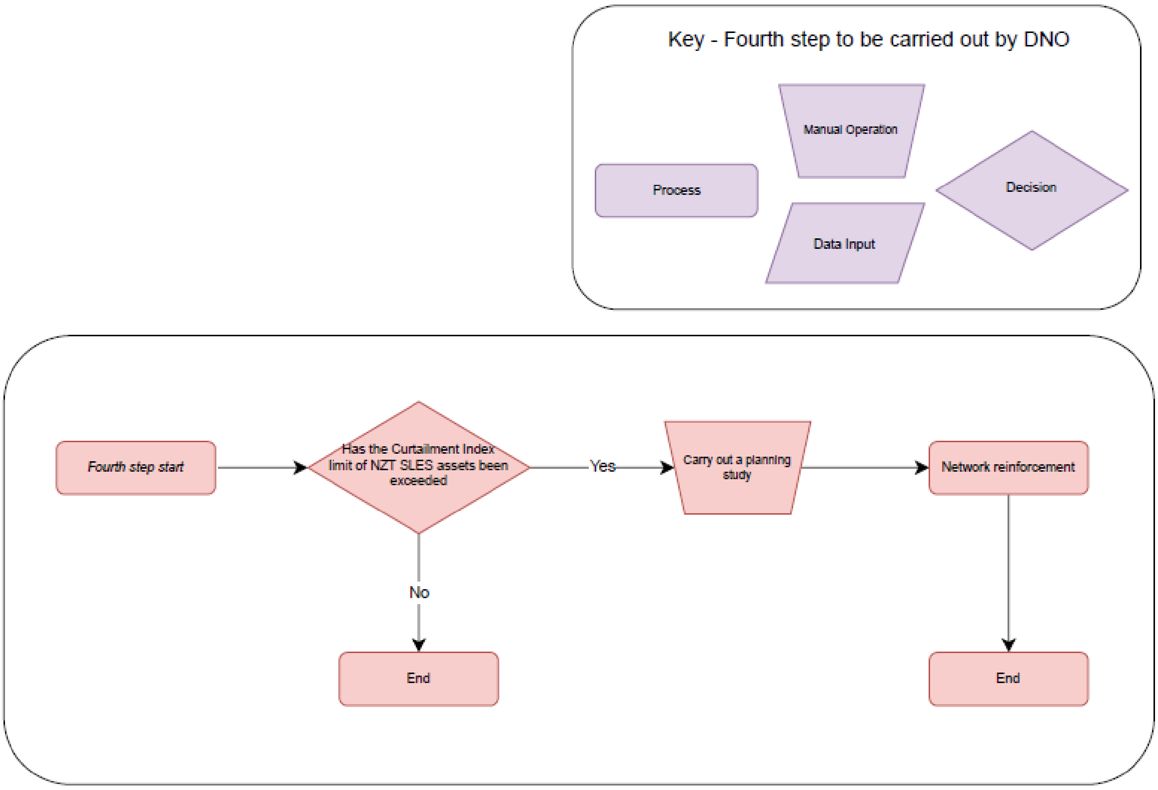

Figure 3-12: Flowchart describing the fourth step process

4 Glossary

CEMS
Community Energy Management System - monitors, controls and optimises energy generation, storage and consumption within the community and establish flexibility potential to the grid

HEMS
Home Energy Management System – monitors, controls and optimises energy generation, storage and consumption within a household

LSOA
Lower Layer Super Output Area is a geographical area used in the 2021 census that comprise between 400 and 1,200 households and have a usual resident population between 1,000 and 3,000 persons

LV Affirm
Excel workbook used by the ENWL connections team to carry out LV connection studies

Pre-Sense
AI enables, edge computing LV monitor that captures key metrics of network health to support proactive network management strategies for DNOs. Installed at substations and other supply points on the DNO network capturing high resolution power flow data

Total Harmonic Voltage Distortion
r.m.s. value of individual harmonic voltages, expressed as a percentage of the fundamental r.m.s. voltage

Sapient
Cloud based server holding all Presence LV monitoring data

SLES
Smart Local Energy System – A group of assets together within a local area operating in a smarter more efficient way

Weezap
Advances vacuum circuit breaker based switch and recloser. It allows DNOs to adjust supply arrangements to connected circuits remotely and dynamically, in line with changing load and supply conditions