Vulnerability Assessment

Results for Project SµRF

May, 2023 – Version 1.2

Document Control

Change History

Version	Issue Date	Author	Description
1.0	1/4/2023	Adam White	Initial Draft
1.1	1/5/2023	Bill Tarlinton	Review
1.2	20/9/2023	Adam White	Update based on feedback from SμRF team

Referenced Documents

Version	Issue Date	Author	Description

Table of Contents

1 INTRODUCTION

1.1 PURPOSE

This document summarises the methodology used to determine the vulnerability of electrical network infrastructure and provides a set of results for the Eurobodalla region.

1.2 CONTEXT

The vulnerability analysis described within this report is part of a larger reliability feasibility project, the Southcoast μ-grid Reliability Feasibility (SμRF) project. The overall project centres around the deployment of islandable microgrids that act like mini electricity grids, capable of keeping local energy networks powered when they are cut off from the national system.

Overall, the research project seeks to understand if and how microgrids could help achieve a resilient, reliable and equitable energy future for people in the Eurobodalla (a shire on the South coast of New South Wales).

1.2.1 Electrical Infrastructure

While electrical infrastructure underpins modern life, the components that enable energy to be delivered thousands of km across the country in real-time often go unnoticed.

There are a number of key components that are closely integrated to enable the service that many of us take for granted.

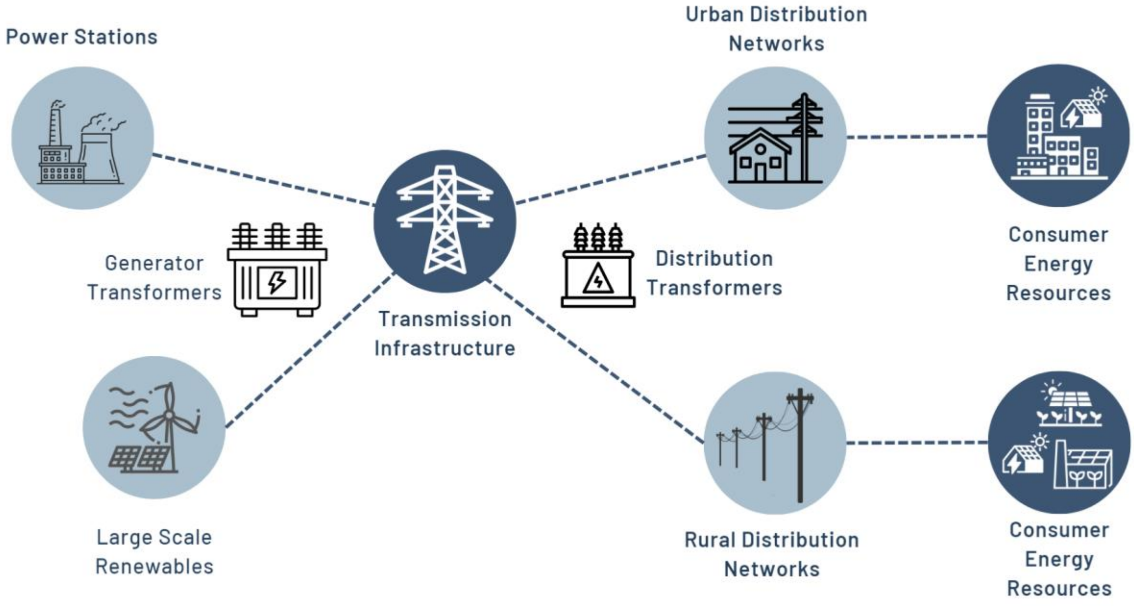


Figure 1 – Electricity System Infrastructure

Figure 1 provides a high level of view of these components:

- Traditional Power Stations: Are a source of centralised generation that have historically underpinned the operation of the electricity system. Technologies include coal, open cycle gas, closed cycle gas and hydro. The proportion of energy sourced from these traditional generators is declining, however they currently do make a very important contribution to meeting evening energy demand.

- Large scale Renewables: main source of new generation capacity, these generators convert variable solar and wind resources into electrical energy. These low cost sources of energy will underpin energy supply within the 21st century energy system. Similarly, to traditional generators, these energy sources often require energy to be transported great distances to reach energy users & communities.

- Transformers: allow for electricity to be converted 'up' into high voltages suitable for transmission over long distances, and then back 'down' to enable that electricity to be safely used by communities.

- Transmission Infrastructure: These lines criss-cross the country moving electricity from the key locations of traditional and large-scale renewable generators to the major population centres. These are the energy 'superhighways' of the system.

- Distribution Networks: are responsible for delivering energy within your local area. They typically take electricity from a transmission connection point on the edge of a residential area and distribute that power across suburbs. In regional areas the distribution network can span large areas, transporting electricity across a whole region. It is these local factors that can have a large impact on the quality of the electricity supply services you receive.

- Consumer Energy Resources (CER): are small scale generation assets owned by consumers installed behind the consumer's energy meter. These CER assets include solar generation, battery energy storage, electric vehicles, and responsive smart home appliances.

1.2.2 Microgrids

A microgrid is a small-scale power grid, including small generators and optionally energy storage units, that can operate independently or collaboratively with other microgrids, or with the main distribution network. Microgrids may provide one way of improving the resiliency of power supply.

1.2.3 Distribution Network

The distribution network is the part of the electricity system we are undertaking the vulnerability assessment on, as the distribution network is the cause of 99.4%[1] of all

[1] https://www.aemc.gov.au/sites/default/files/content/1cf4c35a-87cf-4947-bba0-2ecc8b66def2/Fact-sheet-What-is-reliability.pdf

electricity supply disruptions and is responsible for suppling the 'local area', making it the primary interface point for any microgrid deployment.

The causes of power interruptions to customers range from equipment failure through to major bushfire events.

Figure 2 provides a generic view of the sub-systems that make up the distribution network. Distribution 'feeders', highlighted in yellow, are the high voltage lines that you may notice driving around your local area. These often have the most exposure to the elements and bushfires as they can travel over relatively long distances, often through forested areas, and are strung on wooden poles. This part of the network will be the focus of the vulnerability analysis.

Below these 'feeders' are the 'Low Voltage feeders', these are the lines that run down your street connecting each house to the national electricity system. These same lines will often be used as part of a microgrid deployment.

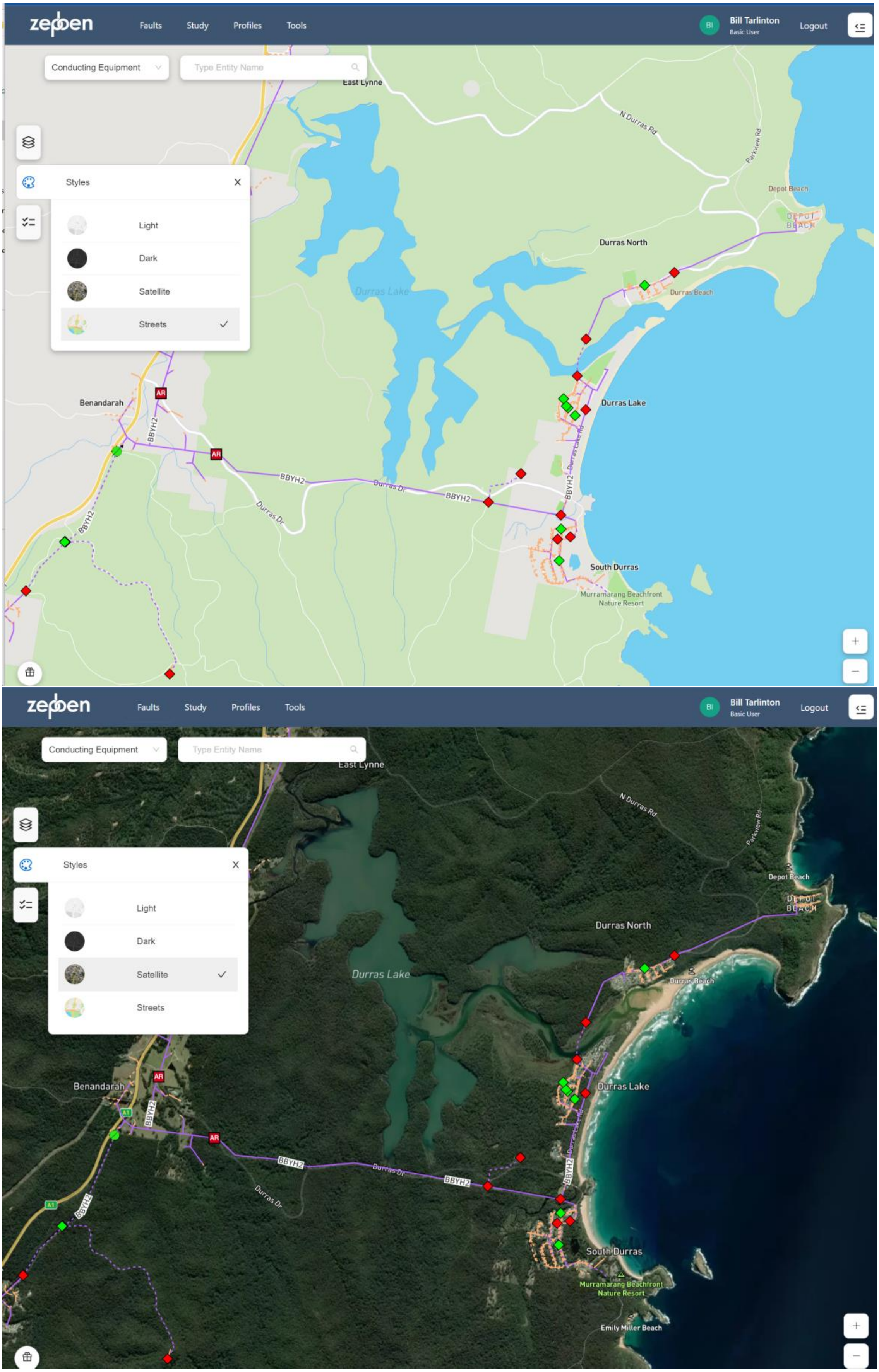


Figure 3 on the following page shows a distribution network powerline (in purple) running through several kilometres of bush. The "low voltage feeders" are shown in orange. The fist image is a simplified map view, making it easy to see the electrical network equipment. The second image has a satellite view as a backdrop, making it possible to see vegetation and other features in relation to the distribution network assets.

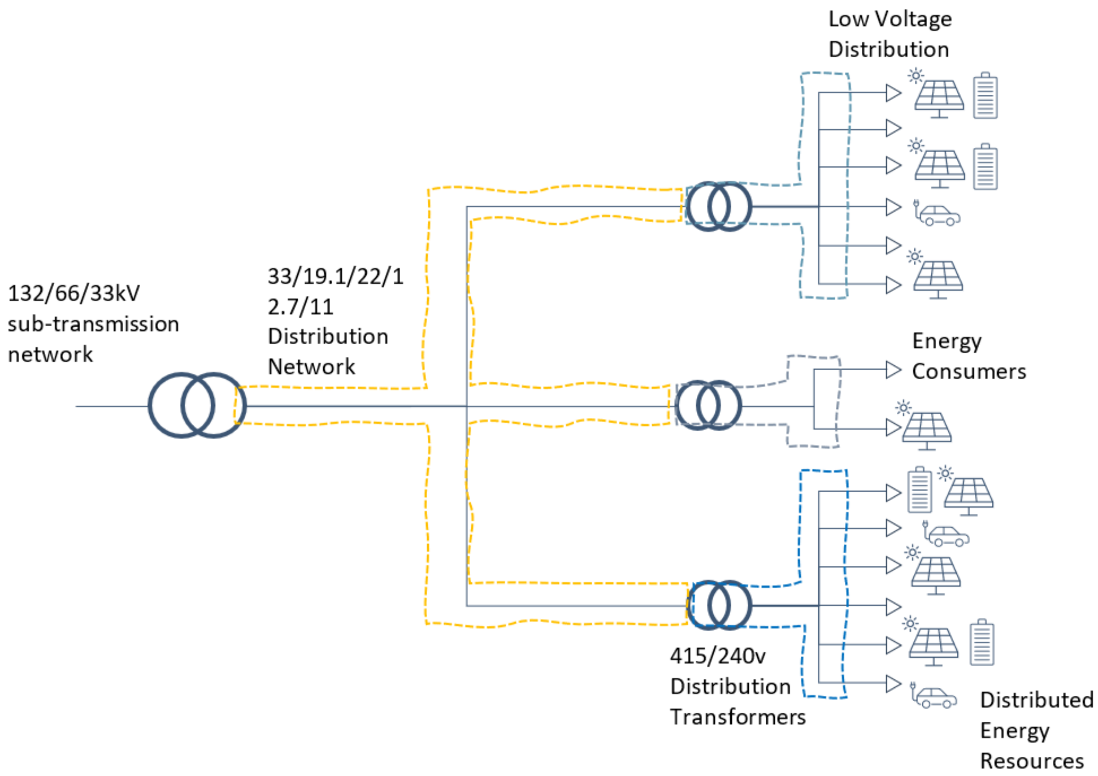


Figure 2 - Components of the Distribution Network

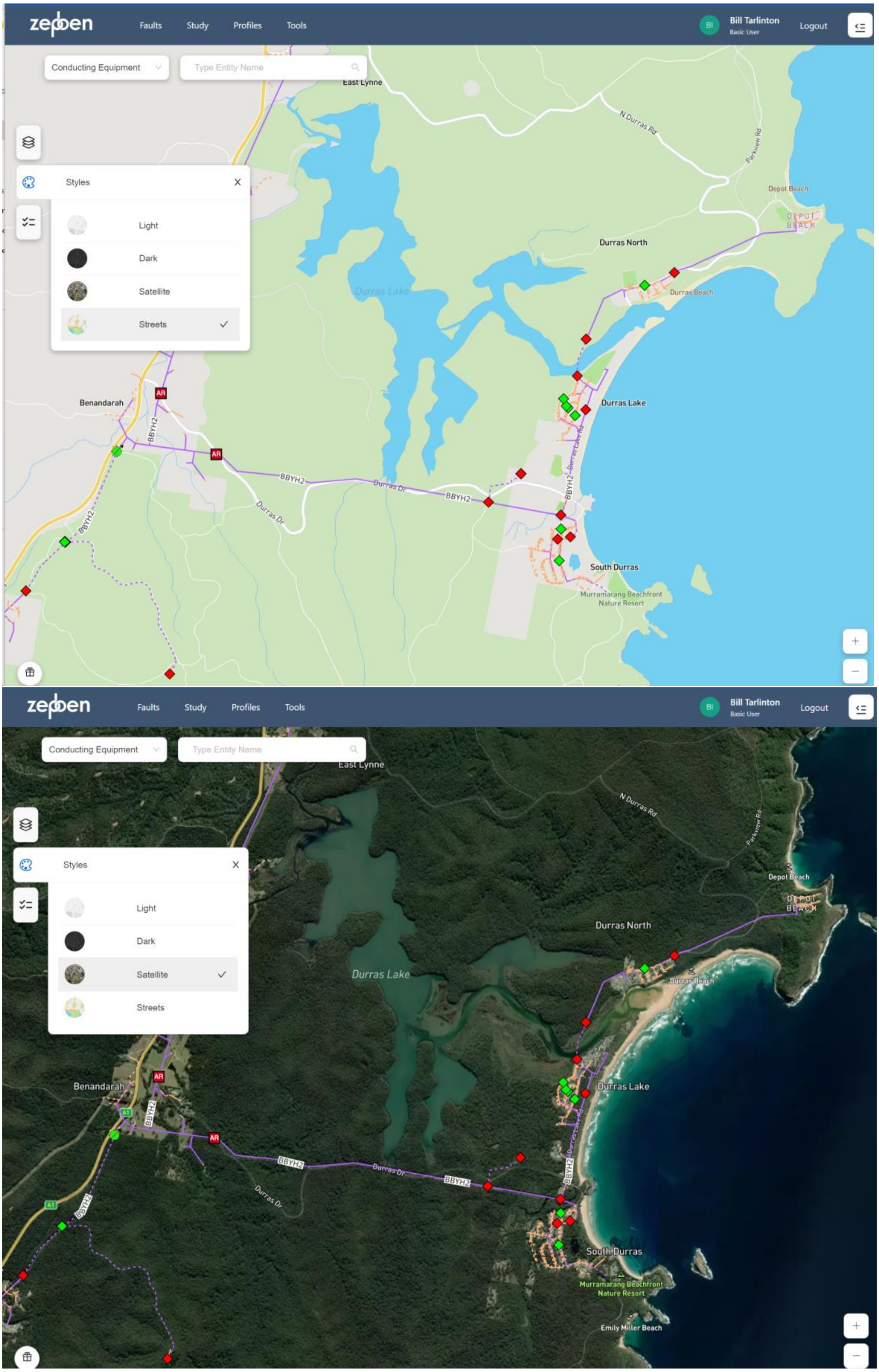


Figure 3 – A distribution network feeder travelling through bush

2 APPROACH

2.1 OVERVIEW

Vulnerability is defined within the biophysical sciences as "*a function of the frequency and severity of a given type of hazard*"[2]. In the context of assessing the outcomes communities can expect from local electricity network infrastructure, we are focusing on quantifying the susceptibility of physical assets to damage (frequency occurrence), and the impact of this on the supply of electricity to a local community (severity).

The core activities proposed to develop a clear view of network vulnerability are:

- Ingest a comprehensive collection of historic fault records and network performance statistics,
- Undertake detailed analysis of the historic network performance, to determine dependant and independent segment level performance, where a segment refers to a section of the network that will be automatically disconnected if a fault occurs,
- Characterisation of network performance as expected fault rates and repair time,
- Assess segment vulnerability, and
- Interpretation and visualisation of segment vulnerability results.

2.2 SUPPORTING TECHNOLOGY SOLUTION – ENERGY WORKBENCH

The key capability required to enable assessment of the vulnerability of local electrical network is a digital model of the infrastructure and its connectivity. Zepben has developed a software platform that makes this model readily available for research, allowing users to programmatically manipulate this digital model to undertake a wide range of studies of infrastructure performance.

Zepben's Energy Workbench platform is based on the IEC Common Information Model (CIM)[3], and is focused on the end-to-end modelling of distribution networks, handling the ingestion of network models in a range of formats, supporting time series analysis using open-source load flow engines and making it possible to present network performance outcomes visually within a map-based environment.

The functional subsystems that comprise the Energy Workbench are illustrated below in Figure 4

[2] https://www.researchgate.net/profile/Nick-Brooks-3/publication/200032746_Vulnerability_Risk_and_Adaptation_A_Conceptual_Framework/links/0fcfd50ac169e15865000000/Vulnerability-Risk-and-Adaptation-A-Conceptual-Framework.pdf

[3] Common Information Model (electricity) - Wikipedia

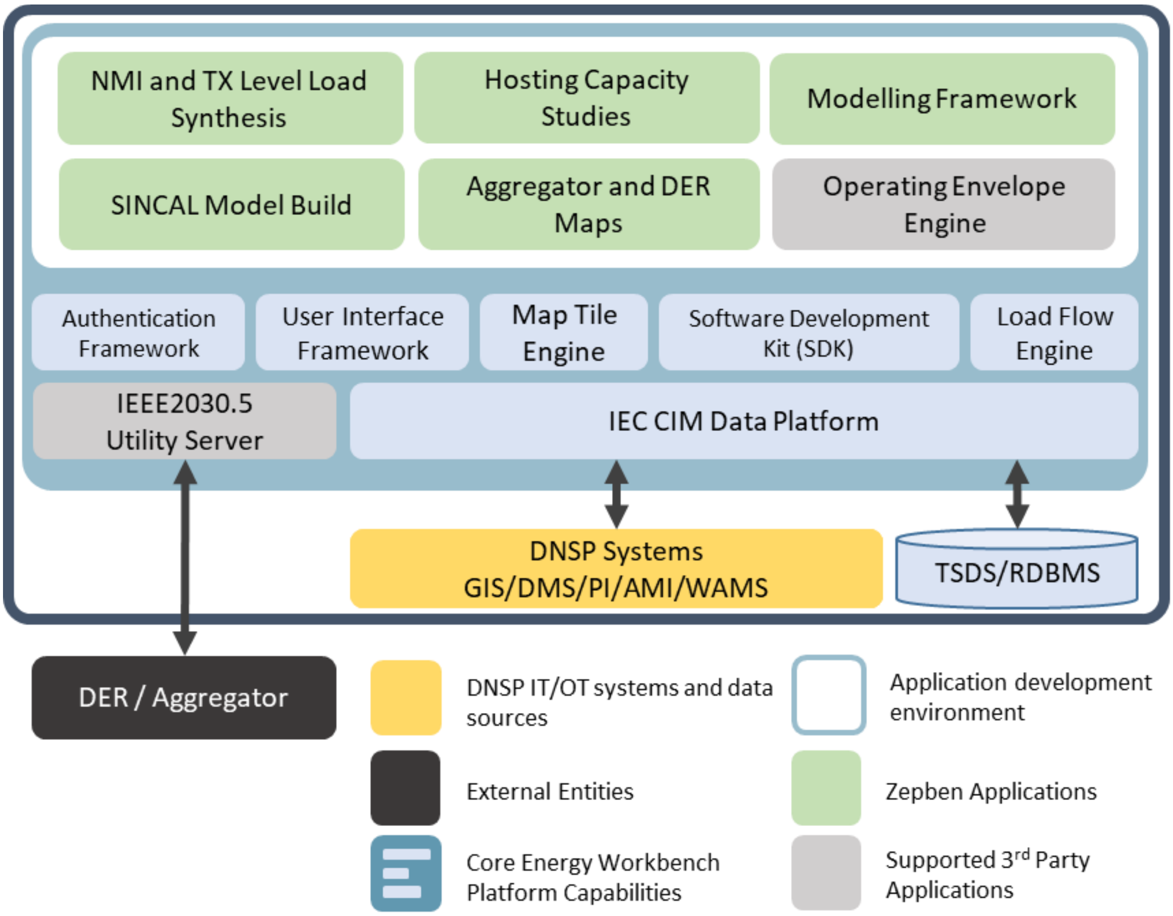


Figure 4 – The Energy Workbench

The elements used within the Energy Workbench platform to complete this project will include:

- DNSP geoJSON Network GIS ingestors: to accept and translate the Essential Energy network model into the IEC CIM data model,
- The Software Development Kit (SDK): to manipulate the network model, data and visualise the network vulnerability, and
- The OpenDSS model builder: to create the OpenDSS[4] models that enable analysis of the local network vulnerability.

[4] https://www.epri.com/pages/sa/opendss

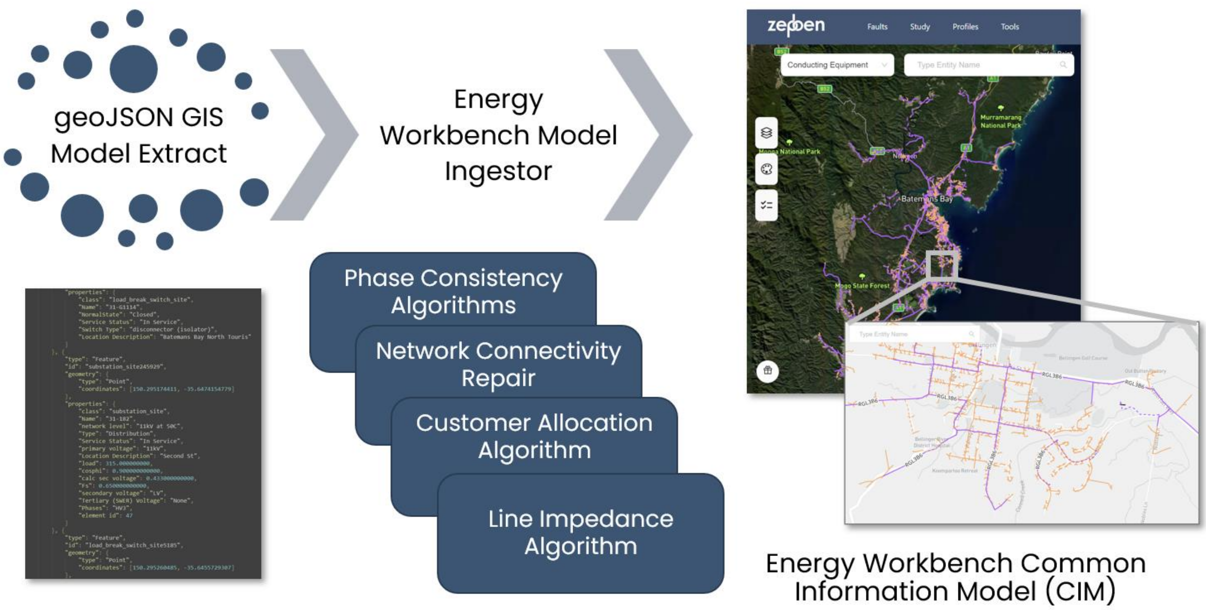
2.3 INPUTS

There are three key inputs into assessing the vulnerability of the distribution network. We do note that these inputs and approach limit us to assessing the vulnerability of grid connected energy supplies, it does enable us to characterise the vulnerability of customers that might be off-grid or be able to temporarily disconnect and operate off-grid.

- **Network Model**: which describes the location, type and connections between the poles, wires and transformers that make up the distribution system.
- **5-year Incident Logs**: network location of the start of the outage, the start and finish times, cause and customer impact.
- **5-year segment reliability statistics**: numbers of connected customers, cumulative outage durations, number of customer interruptions.

2.3.1 Overview of inputs

2.3.1.1.1 Network Model



The digital model of the network is provided to Zepben by Essential Energy as a collection of geoJSON files that reflect the specific location, type, characteristics, and connections for each of the approximately 2 million sections of network that make up the digital model of Essential Energy's 180,000km distribution network.

During the ingestion process of this network model, Zepben analyses the model for missing values and internal consistency, looking for gaps or errors that may prevent use of the model. The identified issues are then repaired during the model ingestion process to ensure that the users of Energy Workbench are able apply the digital model of the network to solve real world problems.

2.3.1.2 5-years of incident logs

SUPPLY_LOST	SUPPLY_RESTORED	Interruption_Num	Feeder Description	Segment	Custs on Seg	CUSTOMERS_AFFECTED	Duration	CML	OUTAGE_TYPE	INTERRUPTION_CAUSE
1/07/2017 19:09	1/07/2017 21:13	INCD-1538178-a	MPTC2 Broulee	1	1842	61	124	7564	Unplanned	Equip - Fatigue
1/07/2017 22:33	1/07/2017 22:58	INCD-1538178-a	MPTC2 Broulee	1	1842	61	25	1525	Unplanned	Equip - Fatigue
3/07/2017 10:09	3/07/2017 15:10	INCD-57157-g	BBYH2 Nelligen	31-R1291	278	8	301	2408	Planned	Routine Maintenance
3/07/2017 10:09	3/07/2017 14:44	INCD-57157-g	BBYH2 Nelligen	31-R1291	278	28	275	7700	Planned	Routine Maintenance
6/07/2017 8:46	6/07/2017 13:58	INCD-57469-g	BBYF2 Deep Ck	31-R10320	1455	11	312	3432	Planned	New Connection
6/07/2017 8:46	6/07/2017 13:53	INCD-57469-g	BBYF2 Deep Ck	31-R10320	1455	43	307	13201	Planned	New Connection
8/07/2017 17:11	8/07/2017 19:37	INCD-79588-b	BERB2 Wallaga Lake	15-R724	489	1	146	146	Unplanned	Equip - Fatigue
17/07/2017 9:28	17/07/2017 13:33	INCD-57554-g	BODC2 Potato Pt	1	468	454	245	111230	Planned	Augmentation
17/07/2017 9:28	17/07/2017 13:33	INCD-57554-g	BODC2 Potato Pt	31-R13503	164	158	245	38710	Planned	Augmentation
18/07/2017 8:35	18/07/2017 13:35	INCD-57682-g	NARF2 Tilba	1	417	13	300	3900	Planned	Routine Maintenance
18/07/2017 8:35	18/07/2017 13:35	INCD-57682-g	NARF2 Tilba	1	417	3	300	900	Planned	Routine Maintenance
19/07/2017 16:23	19/07/2017 19:46	INCD-68504-h	MYT3B6 Moruya Nth	31-R10321	646	1	203	203	Unplanned	Equip - Incorrect Tension
20/07/2017 8:31	20/07/2017 14:27	INCD-57796-g	MPTD2 Surf Beach	31-R1271	1895	91	356	32396	Planned	New Connection
20/07/2017 9:30	20/07/2017 14:06	INCD-57581-g	BERB2 Wallaga Lake	15-R2030	10	7	276	1932	Planned	Routine Maintenance
20/07/2017 9:30	20/07/2017 14:27	INCD-57581-g	BERB2 Wallaga Lake	15-R724	489	1	297	297	Planned	Routine Maintenance
20/07/2017 9:30	20/07/2017 14:06	INCD-57581-g	BERB2 Wallaga Lake	15-R724	489	467	276	128892	Planned	Routine Maintenance
21/07/2017 9:35	21/07/2017 14:11	INCD-57871-g	BBYF2 Deep Ck	31-R10255	17	3	276	828	Planned	Routine Maintenance
26/07/2017 9:12	26/07/2017 13:56	INCD-57944-g	NARF2 Tilba	1	417	35	284	9940	Planned	Tree Clearing
26/07/2017 16:55	26/07/2017 21:04	INCD-1559425-a	MPTB2 Tomakin/Rosedale	1	729	1	249	249	Unplanned	Unauth Contact - Road Vehicle
2/08/2017 9:10	2/08/2017 14:00	INCD-58006-g	NARF2 Tilba	31-R10213	81	78	290	22620	Planned	Tree Clearing
2/08/2017 9:47	2/08/2017 13:44	INCD-58057-g	NARF2 Tilba	31-R13062	101	72	237	17064	Planned	Routine Maintenance
2/08/2017 10:00	2/08/2017 11:00	INCD-1559260-a	MPTD2 Surf Beach	31-R1271	1895	1	60	60	Planned	Routine Maintenance
5/08/2017 18:08	5/08/2017 21:46	INCD-1569008-a	NARF2 Tilba	31-R13057	178	81	218	17658	Unplanned	Equip - Mech Fail - CB/ABS/Trans
11/08/2017 9:20	11/08/2017 15:17	INCD-59140-g	NARF2 Tilba	31-R13057	178	44	357	15708	Unplanned	Urgent Network Repair
11/08/2017 9:20	11/08/2017 15:17	INCD-59140-g	NARF2 Tilba	31-R13057	178	37	357	13209	Unplanned	Urgent Network Repair

These logs are captured by Essential Energy to provide highly granular tracking of outage incidents that occur on the network, from a 10 second momentary interruption for one customer, through to the loss of a major regional supply point impacting tens of thousands of customers.

Each incident log tracks:

- The date and time of the loss of supply (electricity),
- The date and time of the restoration of supply (electricity),
- The electrical feeder involved,
- The segment (section of network),
- Customers connected directly to the segment impacted,
- The total number of customers affected (i.e. including downstream customers),
- Duration of loss of supply (electricity),
- Number of minutes customers were without supply (duration times number of customers),

- The type of loss of supply (planned, unplanned, momentary), and
- The cause of loss of supply.

2.3.1.3 5-year segment cause statistics

These statistics are derived from the incident logs and provide tracking of the area of network impacted as well as the segment of network that caused the loss of supply. These logs include a subset if the fields outlined as part of the incident logs.

2.4 OUTPUTS

The output results provide a set of metrics that capture and define the vulnerability of the local network, and include:

- Repair time statistics by network segment,
- Accumulated fault rate by cable segment, and
- Expected number of interruptions by network segment.

2.5 Development of Network Performance Data Metrics

2.5.1 Analysis of Regional Performance

The Eurobodalla region of NSW has historically had significant variation in network performance. The most recent impact to overall network performance was the 2019-20 Black Summer bushfires, where the Eurobodalla was severely impacted. The upper orange line in Figure 5 represents the average number of outages seen by an electricity customer in the Eurobodalla area, while the lower blue line shows the average cumulative duration of these outages. Both lines are on a rolling 12-month basis, and so you can observe a 12-month impact from major events.

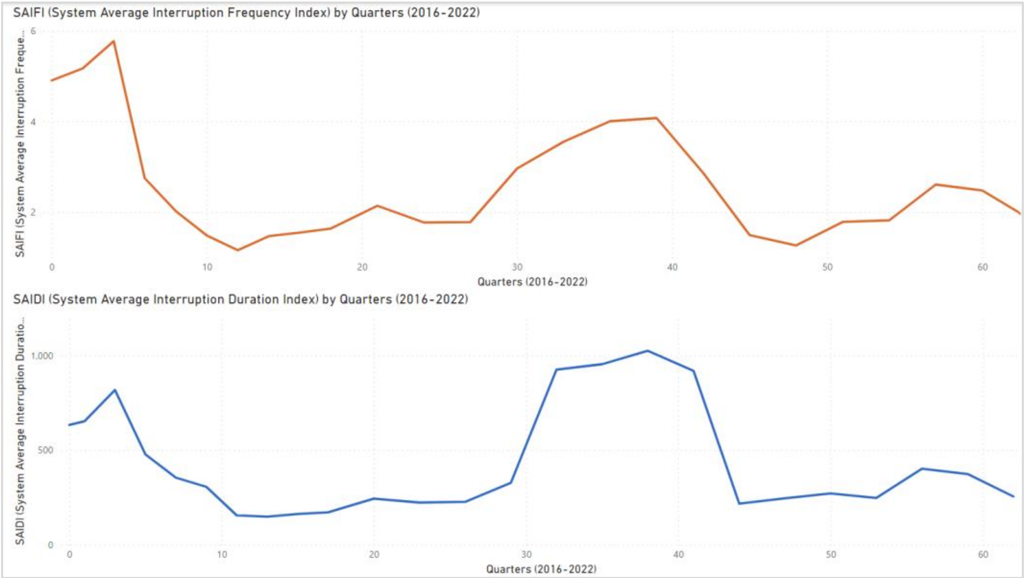


Figure 5 – 12-month rolling regional performance – Eurobodalla NSW

While this level of performance tracking provides an overview of performance level in the region it does not provide insights that allow us to identify the vulnerability of local sections of network, and therefore identify areas best supported by islandable microgrid technology.

2.5.2 Analysis of Feeder Level Performance

Moving to the next level of detail in Figure 6 we can identify that performance below the regional level is not uniform across the region and that overall measured performance can be driven by specific local impacts. The upper chart in Figure 6 depicts the frequency of interruptions per customer, while the lower chart in Figure 6 depicts the average duration in minutes per customer. At this level the data begins to highlight areas that are clearly more vulnerable to loss of supply events, as well as those that are harder to restore once supply has been lost.

However, distribution feeders in the Eurobodalla region have lengths between 12km and 140km. This level is not yet granular enough to identify the particular focus areas for development of islandable microgrids.

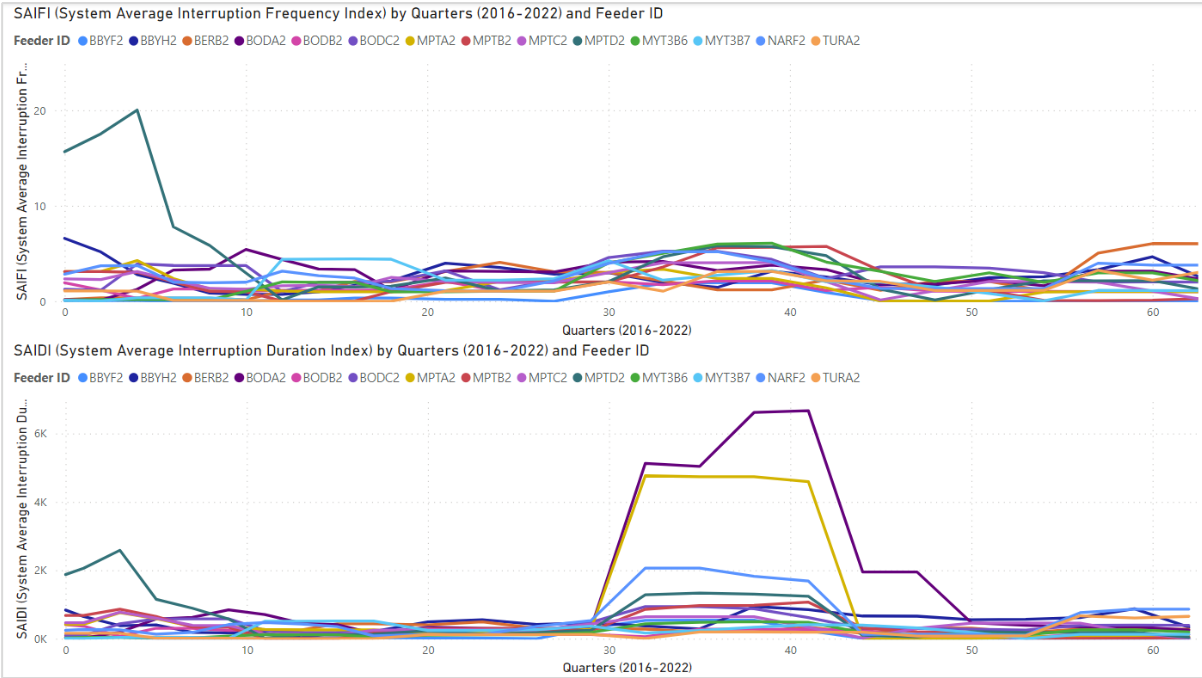


Figure 6 - 12-month rolling feeder performance – Eurobodalla NSW

2.5.3 Segment Level Performance

Analysing one level lower, provides a view of segment level performance. The upper chart of Figure 7 depicts the frequency of interruptions per customer, while the lower chart tracks the percentage of the year that supply was available to customers on each segment of the network.

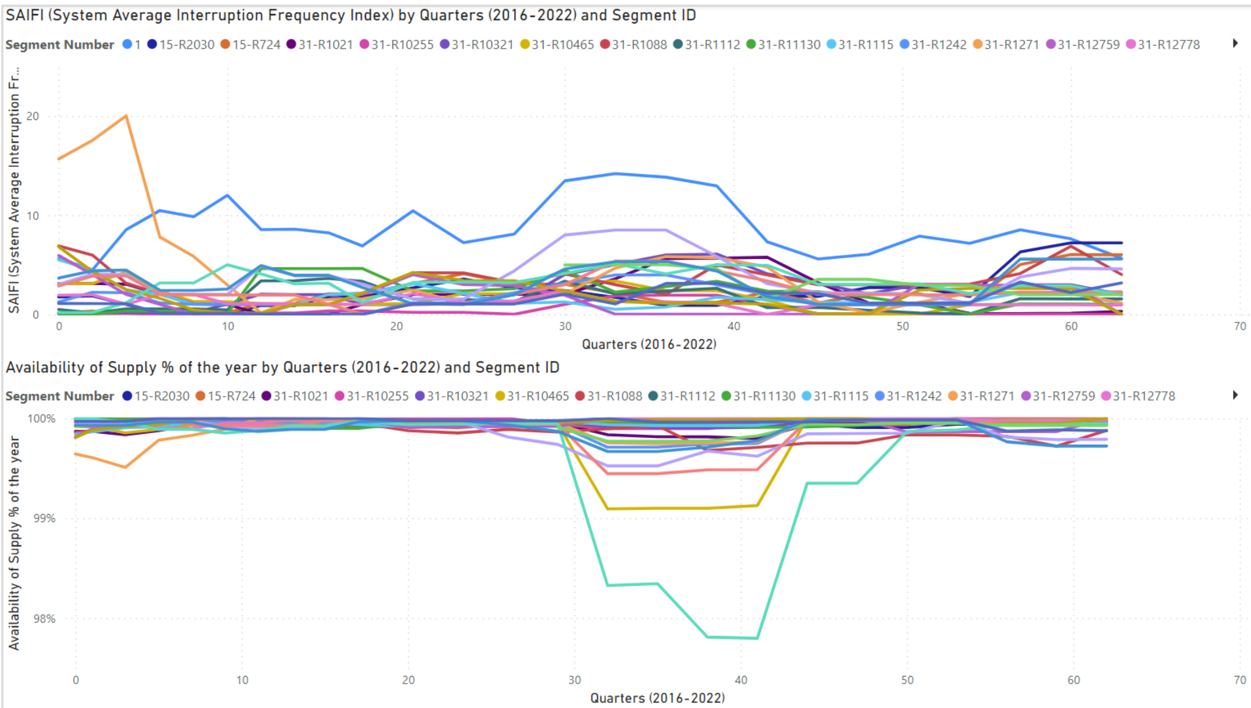


Figure 7 - 12-month rolling segment performance – Eurobodalla NSW

At this level, local impacts can be identified, such as the blue line in the upper chart highlighting a segment that consistently experienced a high number of interruptions above the regional average. Or the green line on the lower chart that highlights the vulnerability of this segment extended restoration times during major events.

It is this level of data that forms the key input into analysis on network vulnerability. As this provides results at the best level to guide analysis and development of islandable microgrid projects.

2.5.4 Segment Level Performance Analysis – Loss of Supply Duration

The initial approach is to determine the repair time statistics for each of the network segments within the region. This is achieved by taking the complete dataset of 2362 loss of supply incidents and aggregating them by the maximum duration of each interruption for each segment. This provides a distribution of interruption duration specific to each segment.

Analysis of the distributions in outage duration collectively shows the loss of supply duration that customers can typically experience when damage occurs to their local network segment. The overall distribution in repair time is not always consistent between segments, due to local factors such as the distance from local depot, difficulty patrolling the powerlines and types of faults that commonly occur.

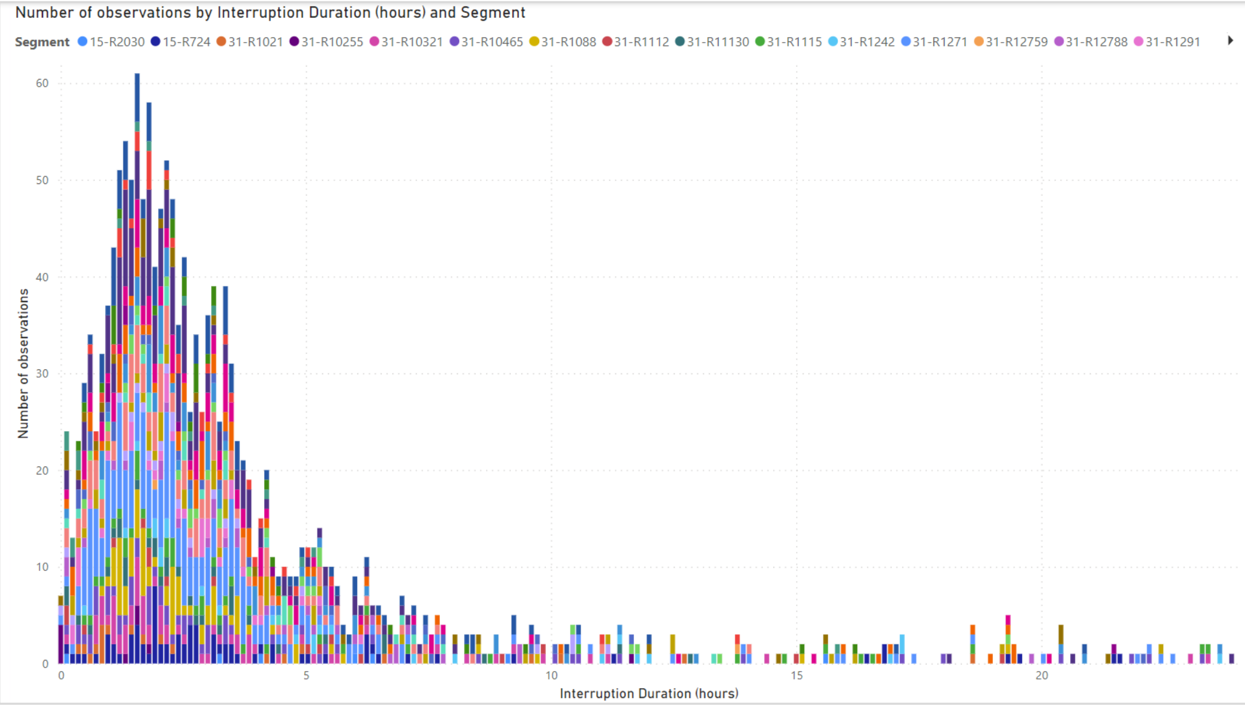


Figure 8 - Breakdown of repair time by segment ID

These local factors create a distribution on repair time for each segment that needs to be considered to generate a realistic picture of the vulnerability of the local network. To incorporate this into the vulnerability assessment the distribution of each segment's repair was assessed to determine mean, median as well as a breakdown of percentiles for each segment repair time.

Figure 9 shows a breakdown of the various percentiles for repair duration by segment. The segments (x-axis), with yellow bars that break through the blue shaded rectangle indicate segments where the 50th percentile (median) of their repair time exceeds 4 hours. Or in other words customer connected to this segment can have a 1 in 2 chance that a supply interruption will last longer than 4 hours.

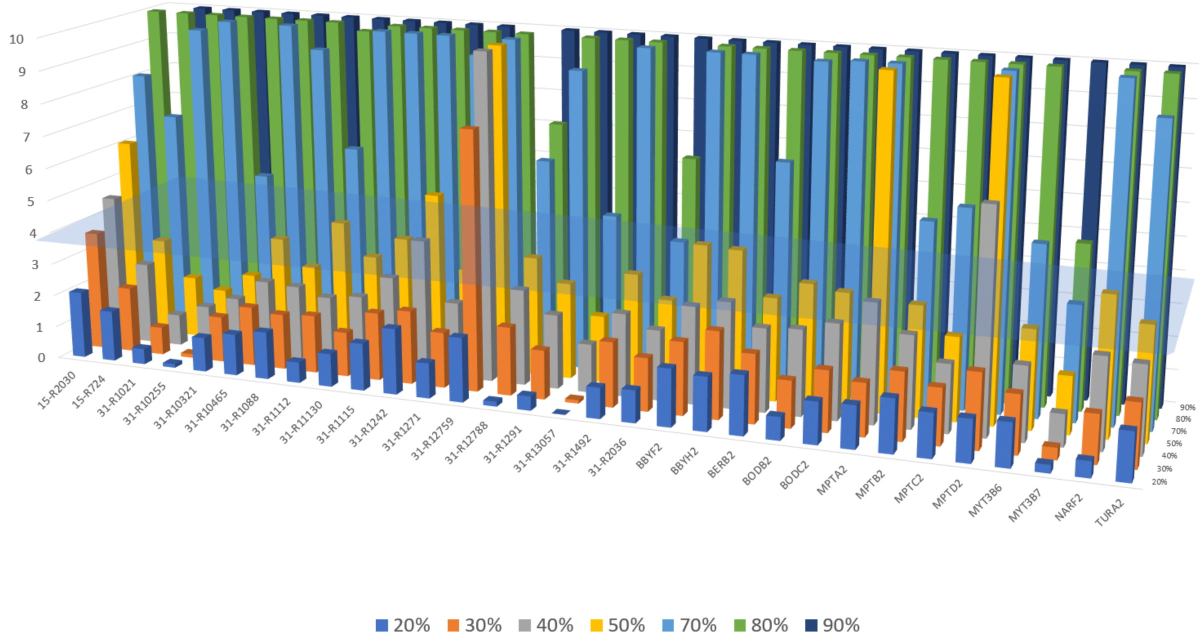


Figure 9 - Segment repair time by percentile

2.5.5 Segment Level Performance Analysis – interruptions by network segment

The vulnerability of the electricity supply is a combination of probability that the upstream network experiences an interruption and the expected repair time required to restore the supply of electricity.

Analysis of the fault rate is a straightforward calculation considering the observed faults that originated on each segment of network against the total segment length. This provided a fault rate per km that can then be normalised on an annual basis. Figure 10 compares the local network segment fault rate performance against the industry accepted typical fault rate of 0.06 fault per km per year for overhead networks.

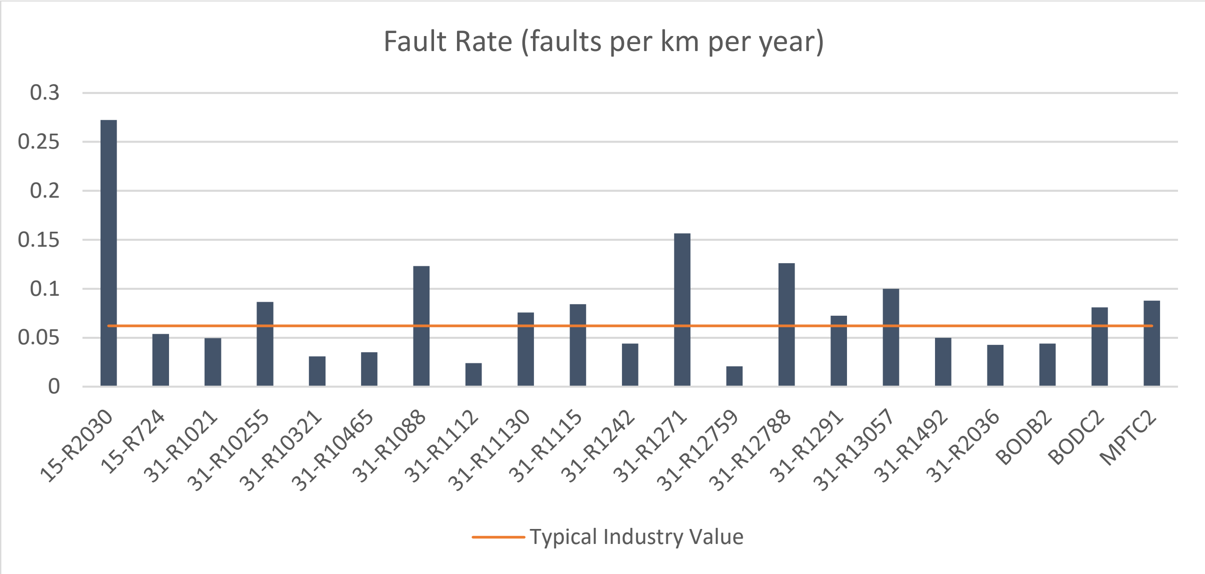


Figure 10 - Fault Rates by Segment ID

Analysing Figure 10 there is a wide range in fault rates across the region, with segments both above and below the industry accepted typical fault rate.

2.6 Vulnerability Analysis

Using the segment-based statistics that characterise the frequency of supply interruptions and the typical repair times as inputs we can quantify the overall vulnerability of local network sections within the Eurobodalla.

These statistics when combined with the network model topology and location of network protection equipment allow for the calculation of the cumulative effect of upstream network failures on the vulnerability of downstream network segments.

For example, when considering the vulnerability of the segment highlighted in pink in Figure 11 below, we also need to consider the upstream network. The typical case is where there is a recloser (which is a "smart" switch that detects faults and opens) located at that head of the segment that isolates any faults that occur on the pink segment preventing them from impacting the yellow network segment. However, any faults on the upstream yellow segment will isolate supply to the pink segment, therefore the frequency of interruptions for the pink segment is the sum of the fault rate for the pink section and all upstream segments.

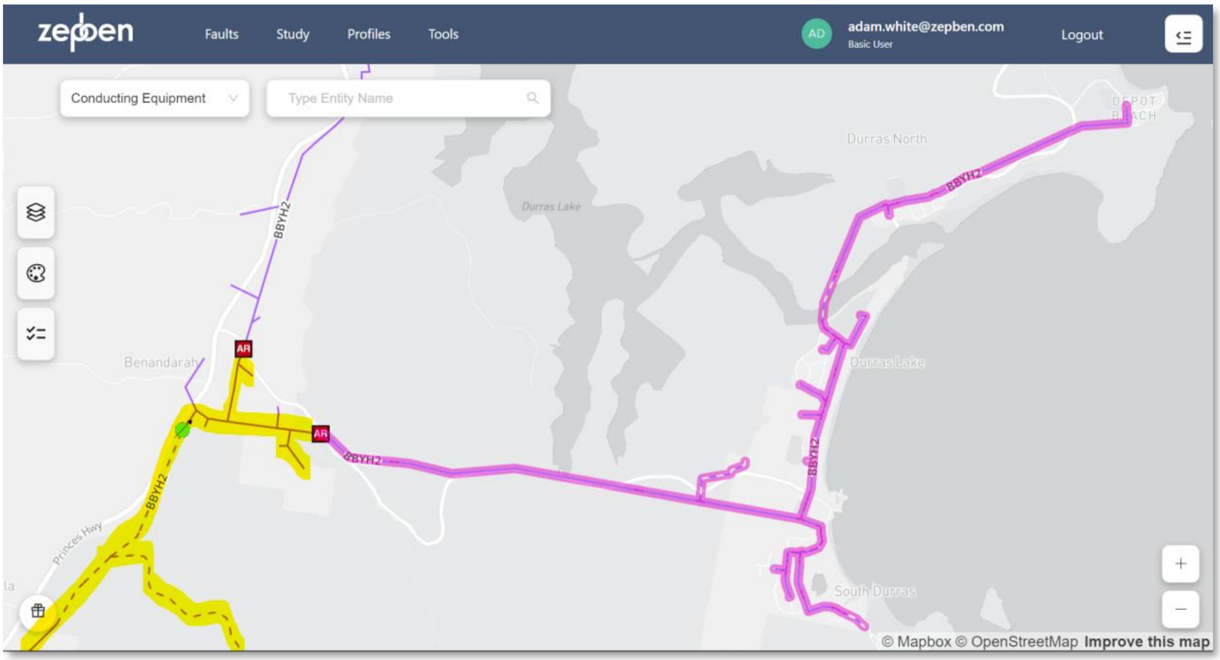


Figure 11 - Example of network segment protected by auto recloser

To extend this simple example across the complete Eurobodalla region, Zepben uses the Energy Workbench platform to build electrical network models for the OpenDSS[5] load flow engine. Using these models, we can apply the built-in reliability algorithms included within OpenDSS to assess the vulnerability of the local network segments.

These OpenDSS models were configured with:

- the specific network protection device characteristics for reclosers and fuses,
- the fault rate determined for each network segment,
- the repair time of interest for assessing vulnerability, where the default analysis value is the median repair time, and
- the percentage of faults that are permanent.

[5] OpenDSS (epri.com)

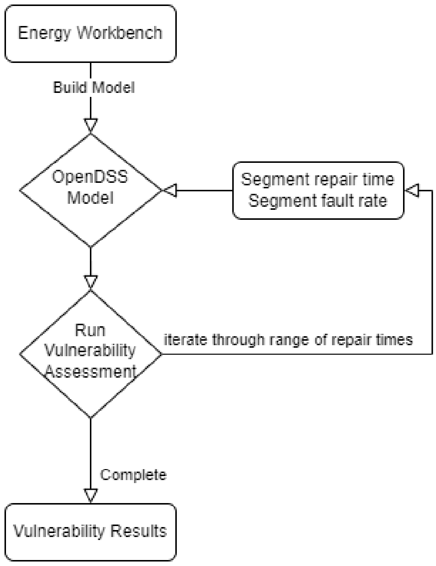


Figure 12 - Vulnerability Assessment Workflow

Once the model is established with these inputs, the OpenDSS reliability algorithm is used to trace upstream and downstream identifying:

- the location of all network protections switches,
- the cumulative fault rate of all network segments,
- the number of interruptions expected,
- the total downstream network km's, and
- the duration of interruptions

These results are captured and written out to form the overall results of the vulnerability assessment. The results are also calculated for a complete range of repair times, enabling each segments exposure to extended repair times to be considered as part of assessing network segments for islandable microgrid suitability.

2.7 RESULTS

This section summarises the results of the vulnerability analysis undertaken for the Eurobodalla region. The analysis has been undertaken on all network feeders in the Eurobodalla region, although the specific network sections that are considered as part of the SuRF project have been defined based on the communities they serve. The review of the results aims to highlight the particular segments of the network that show a high degree of vulnerability to outages, due to their direct exposure of the cumulative impact of the upstream network.

Figure 13 below demonstrates the way the assessment identifies how particular network segments are vulnerable to network outages. The orange and red coloured lines here are those that based on a combination of historic outage performance and network topology have been identified as those most likely to experience supply interruptions in the future.

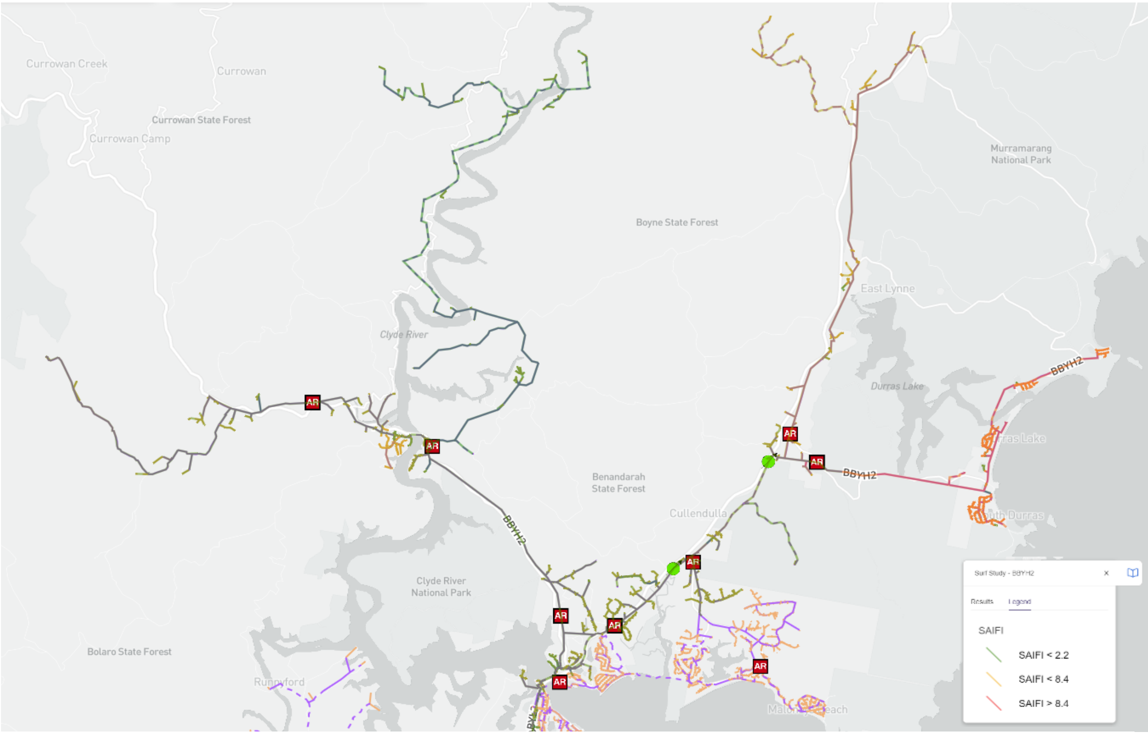


Figure 13 - Example of a single feeder's vulnerability results visualised geospatially using Zepben's Network Explorer

Analysing the whole region's performances allows us to then focus in on particular segments of the network that should be assessed as high value candidates for a reduction in interruption vulnerability. Figure 14 provides a breakdown to help assess this, with the size of each bar representing the cumulative interruptions vulnerability expected by feeder. This interruption risk is managed by how the network is segmented to protect the core of the network when interruptions occur on 'spurs' or sections of the network, looking at each 'block' that make up these bars you can then identify the network segments that have the highest vulnerability to interruption.

The following section details by feeder, the network segments that contribute the most to regional interruption vulnerability.

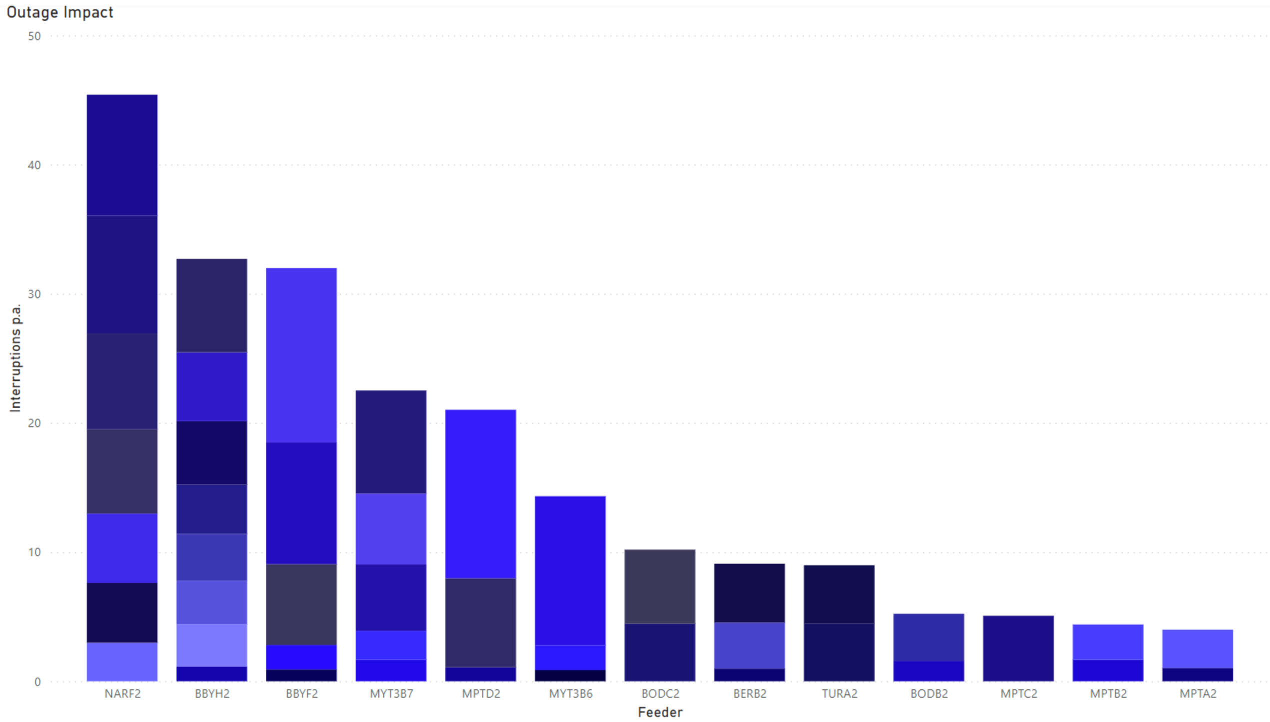


Figure 14 - Breakdown of exposure of interruption by feeder and network segment

2.7.1 Specific Feeder Results

2.7.1.1 NARF2 – Part of North Narooma, Narooma, Corunna, Tilba Tilba, Dignams Creek and Mystery Bay

When looking at the underlying vulnerability of a section of network to interruptions the core driver is exposure, and the core risk mitigation is segmentation. Feeder NARF2 provides a good example of this, while it is a relatively long feeder in terms of total line kms for this region, it is well segmented. This means that there is no one network segment that has extremally high vulnerability, however this segmentation can't avoid the cumulative impact on vulnerability that comes from the total line kms between the start of the feeder and the customers at the end of the feeder, and so the last two network segment 31-R1492 & 31-R12788 are candidates for further assessment.

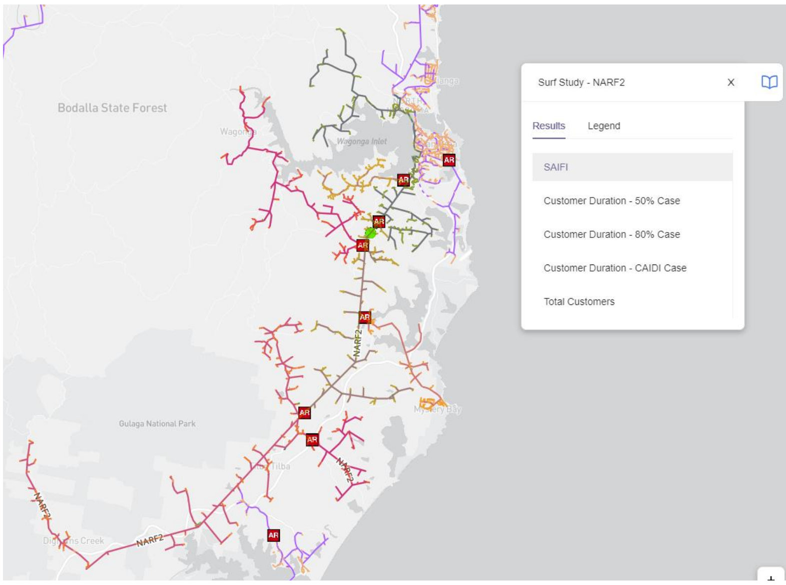


Figure 15 - NARF2 - vulnerability to interruption

Looking at this network segments in more detail, Figure 16, the area highlighted green indicates the extent of the segments which supplies approximately 302 customers. Of these customers there are two pockets that stand out as being candidates for highly localised support, these are highlighted by the orange boxes. Further monitoring and electrical modelling of local network would be required to assess the suitability of these subsections of network to microgrids.

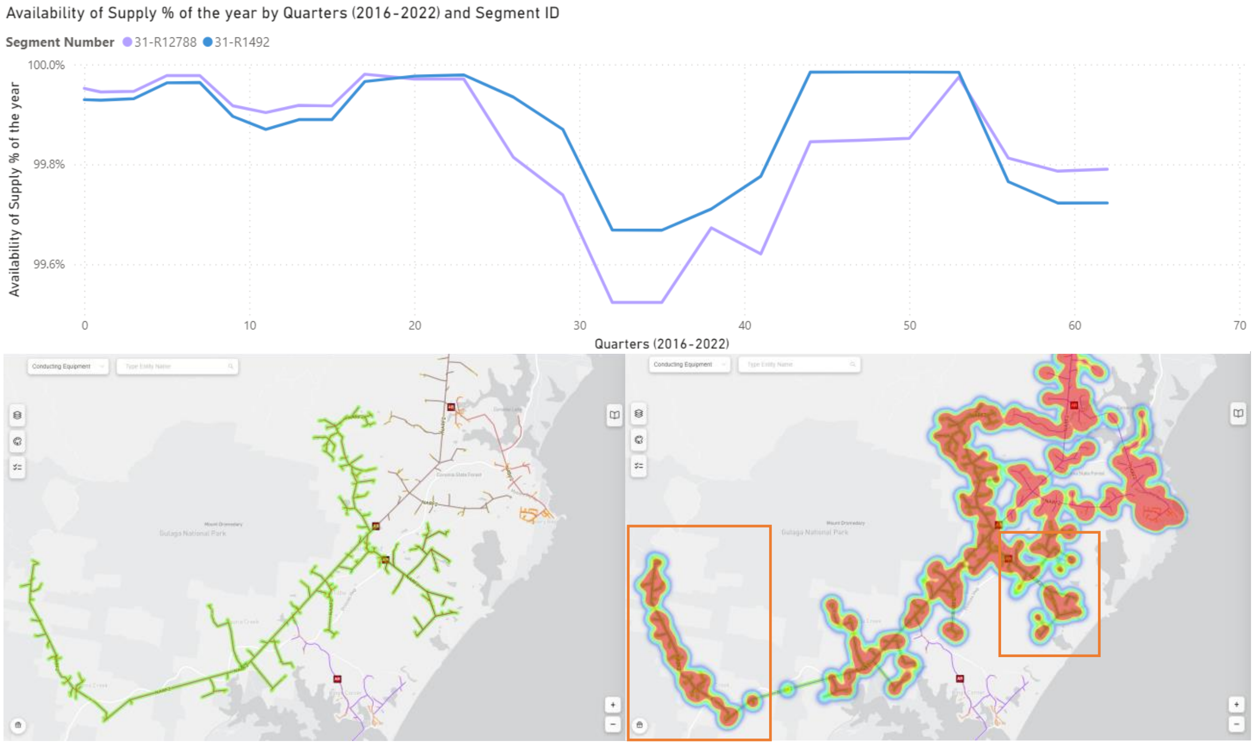


Figure 16 - Network Segment 31-R1492 – Top: profile of historic segment availability – bottom left: highlighted segment – bottom right: Customer heatmap

2.7.1.2 BBYH2 – Part of North Batemans Bay, Benandarah, Depot Beach, North and South Durras, East Lynne, Nelligen and Currowan

Feeder BBYH2 is the second highest for cumulative interruption vulnerability p.a. This is due to the distance traversed by this feeder. Similarly, to BARF2 though this feeder is well segmented to minimise the impact of the vulnerability that comes from line length. The sub-segments that could be considered potential candidates for microgrid based solutions include the Durras Lake/Beach area, Cockwhy and Bullock Creek areas, see the area highlighted by the orange box in Figure 17.

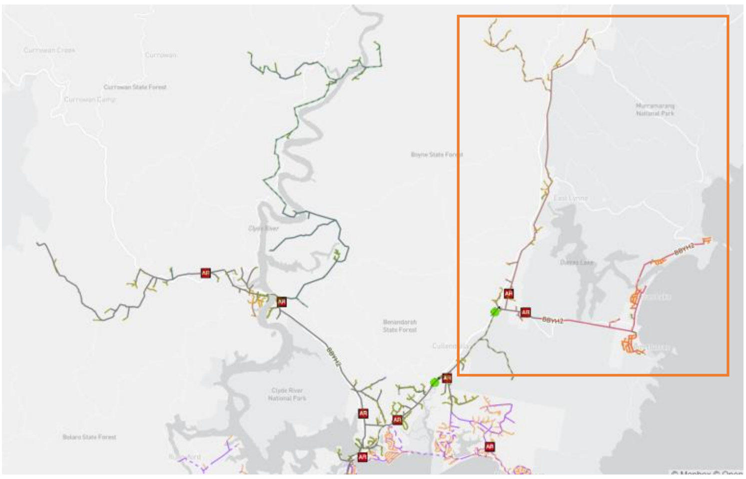
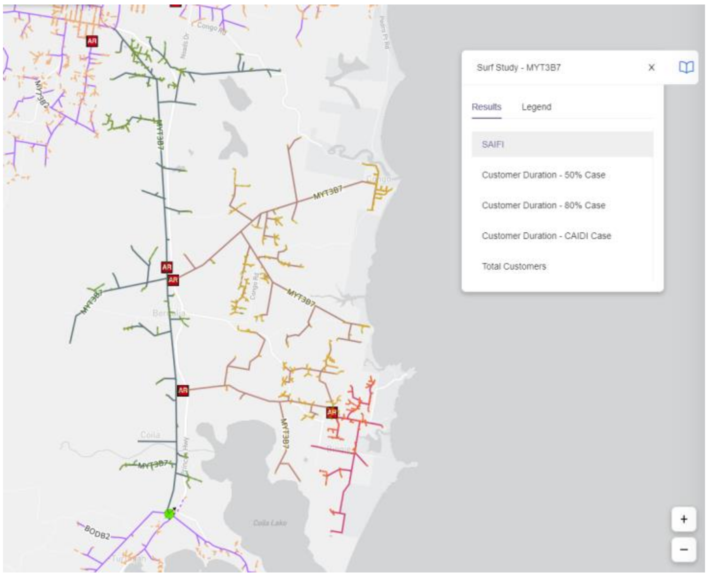


Figure 17 - BBYH2 - vulnerability to interruption



2.7.1.3 MYT3B7 - Congo, Coila and Bingie

This feeder is well segmented but has three network segments that represent 80% of the feeder's vulnerability to interruptions. The communities served by this feeder include Congo, Coila and Bingie. However, on review of these segments against the SuRF projects target area these segments do not fall within the specified focus area for the project.

2.7.1.4 MPTD2 – Rosedale, Guerilla Bay, Malua Bay, part of Mossy point and part of Surf Beach

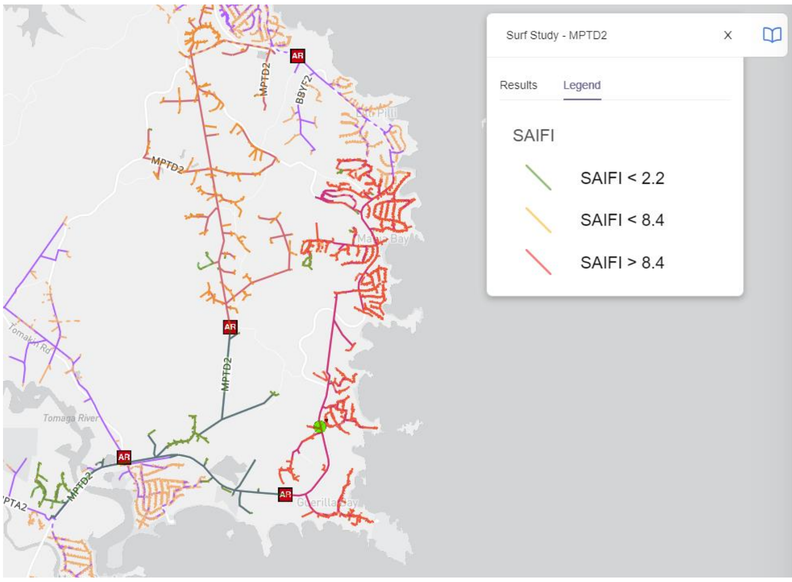


Figure 18 - MPTD2 - vulnerability to interruption

60% of the MPTD2 vulnerability to interruption is concentrated on a single network segment. This segment is within the area considered as part of the SuRF project. This segment 31-R1271 could benefit from additional segregation as the total customer count for network segment is approximately 1889. Due to its size and location, it is also likely to be a difficult microgrid candidate as a complete network segment. This segment could benefit from power flow analysis to identify the local load centres, potentially identifying sub-segments that could be microgrid candidates, reducing the network segments overall vulnerability.

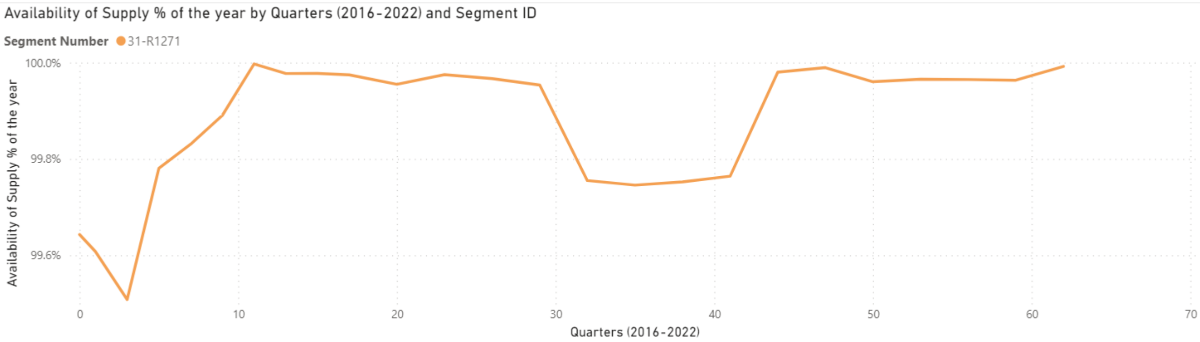


Figure 19 - Trend in segment availability

2.7.1.5 MYT3B6 - Moruya Airport, Moruya Heads, part of Moruya and part of Broulee

80% of vulnerability to interruptions is tied to one network segment on feeder MYT3B6, however this segment it not included in the area under assessment by the SuRF project. The other segments of the feeder show below average vulnerability to interruption.

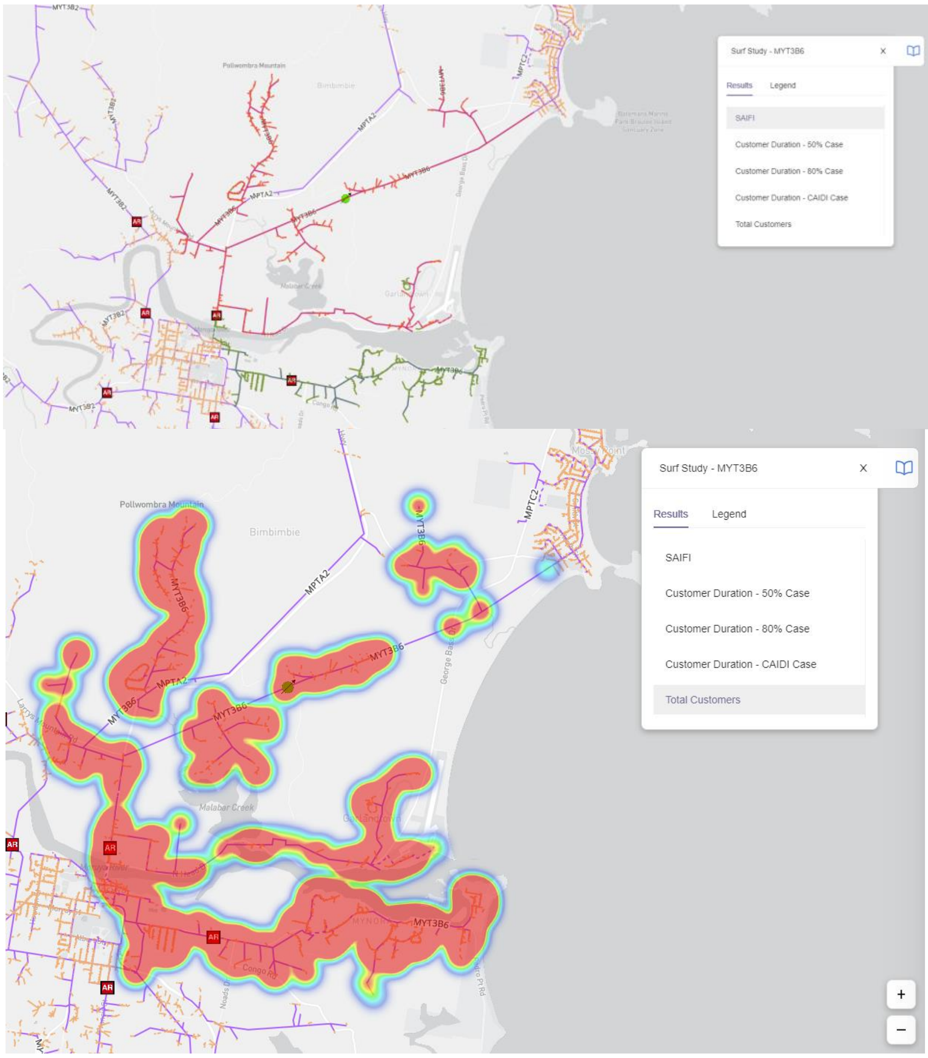


Figure 20 - MYT3B6 – top: vulnerability to interruption – bottom: customer density heatmap

2.7.2 Summary table – Network Vulnerability

Below is a summary table that captures the vulnerability and consequence metrics for the distribution network infrastructure within the Eurobodalla region. Larger values for vulnerability to interruption indicate higher exposure for the infrastructure serving the list localities, and larger value for the consequence of interruption indicate challenges for supply restoration for the infrastructure serving the listed localities.

Table 1 - Network Vulnerability Summary

Feeder (North to South)	Localities	Vulnerability to interruption (interruptions p.a.)	Consequence of Interruption (average duration minutes)
BBYH2	Part of North Batemans Bay, Benandarah, Depot Beach, North and South Durras, East Lynne, Nelligen and Currowan	32.7014539	117.7264056
BBYF2	West Batemans Bay, Edgewood, Lilli Pilli, Runnyford	31.99194172	476.0644446
MPTC2	Mossy Point, Broulee	5.072343646	81.04287554
MPTD2	Rosedale, Guerilla Bay, Malua Bay, part of Mossy point and part of Surf Beach	21.01816456	415.838309
MPTB2	Barlings Beach, Tomaga River	4.395155147	49.97002841
MPTA2	Jeremadra, Mogo	3.993815	11.91448905
MYT3B6	Moruya Airport, Moruya Heads, part of Moruya and part of Broulee	14.32561343	55.16201566
MYT3B7	Congo, Coila and Bingie	22.51272585	56.51300142
BODB2	Trucketabella, Turlinjah, Tuross Lake	5.226565617	7.890955621
TURA2	Tuross Head	8.982649785	110.9466497
BODC2	Potato Point, Lake Mummuga, Bodalla	10.1913706	184.2648823
NARF2	Part of North Narooma, Narooma, Corunna, Tilba Tilba, Dignams Creek and Mystery Bay	45.41287794	98.02130168
BERB2	Beauty Point, Akolele, North Bermagui	9.104827545	33.80205315

Discussion of summary table for distribution network vulnerability

MYT3B6, MPTD2, MYT3B7, BBYF2, BBYH2 and NARF2 show significant vulnerability to experiencing interruptions. Based on the detailed review of the vulnerability results and the network topology, these areas are impacted by a combination of either high network length or are required to traverse pockets of challenging terrain with high degrees of fauna and flora exposure. These are two key contributors to vulnerability of the infrastructure in the Eurobodalla region. Refer to section 2.7.1 for detailed commentary on specific localities.

Vulnerability or exposure to interruption only provides half the picture when it comes to assessing the experience of residents supplied by energy infrastructure in the Eurobodalla. In assessing these results to value investment aimed at reducing local vulnerability, such as microgrids, the consequence of an interruption occurring should also be assessed. A key factor in the consequence is the duration an interruption lasts, this can be due to a multitude of factors, such as accessibility, infrastructure design and natural environment for example.

When assessing the consequence both BBYF2 and MPTD2 are identified as vulnerable to longer duration events historically. Contributors to this has been the impact of the Black Summer bushfires, and vegetation blown into network infrastructure. Although we do recognise that the duration of an interruptions is not the sole measure of consequence, and that other factors such as number of customers, type of customers and infrastructure supported are really important factors in assessing the overall consequence of interruptions to a particular section of electrical infrastructure.