Distribution Network Planning using JuDGE

Anton Aish and Alex de Beer

Supervised by Andy Philpott and Tony Downward

Background

Electricity providers are facing unprecedented levels of uncertainty in future demand for electricity[1].

A key contributor to this uncertainty is the response to climate change, including increased uptake of new technology such as electric vehicles.

[1] Vector (2021). *Vector Electricity Asset Management Plan 2021–2031.*

Background

In addition to conventional line upgrades, electricity providers are also increasingly considering the use of non-wires alternatives, including batteries and techniques for load reduction.

ENERGY NEWS

www.energynews.co.nz

Published on *Energy News* (https://www.energynews.co.nz)

Home > Vector eyes 'non-wires' tech for Warkworth

Vector eyes 'non-wires' tech for Warkworth

Eamon Rood - Wed, 26 Jan 2022

Vector is looking into 'non-wires' alternatives – such as batteries, solar and digital platforms – to help manage rapid customer growth in Warkworth.

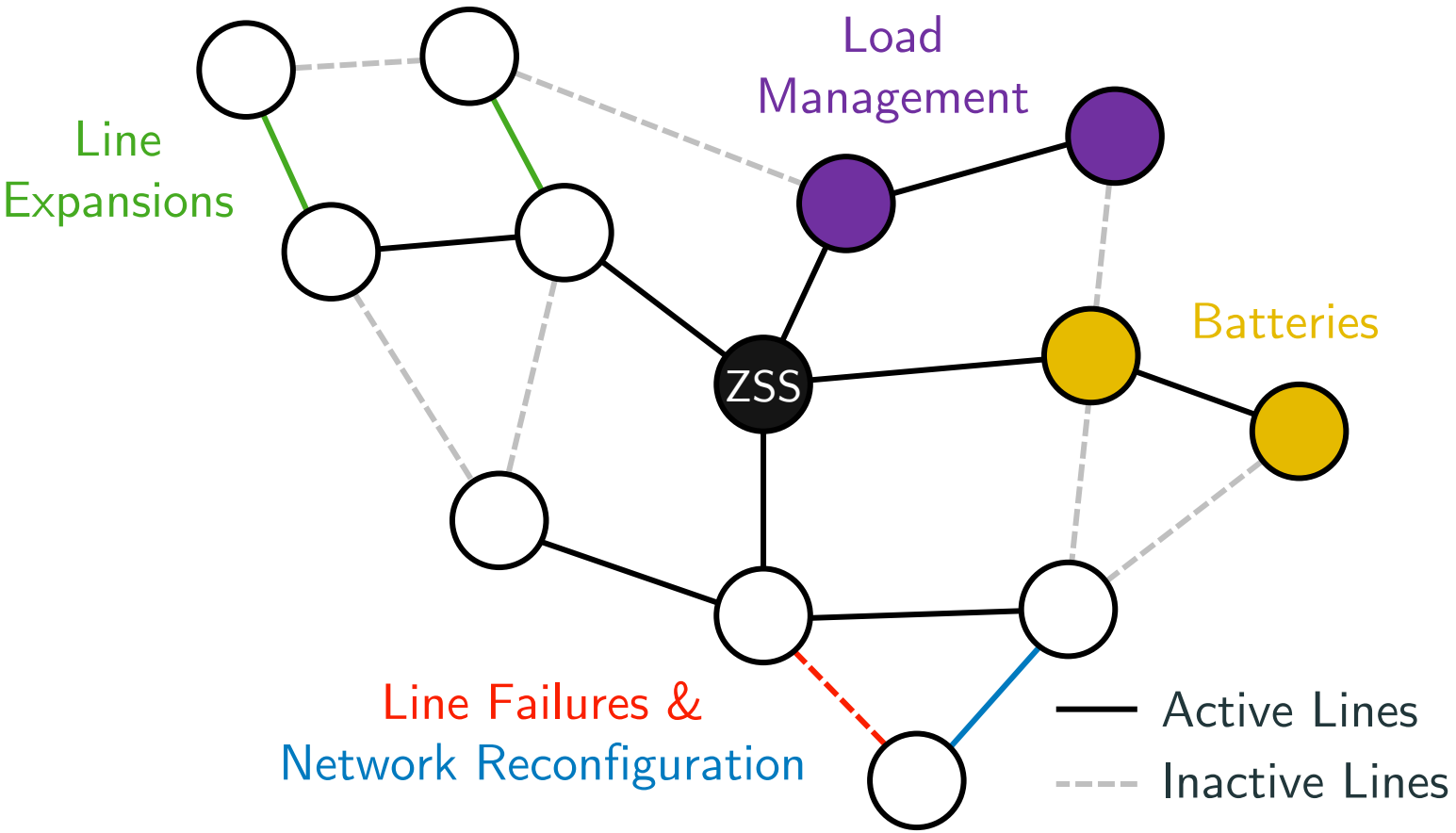
The Auckland lines company forecasts customer numbers will grow by 56 per cent in Warkworth over the next 30 years – from 16,000 today to 25,000. It expects to see constraints on its existing infrastructure within the next decade.

Research Objective

The objective of this research is to use stochastic programming to develop capacity expansion plans for distribution networks that

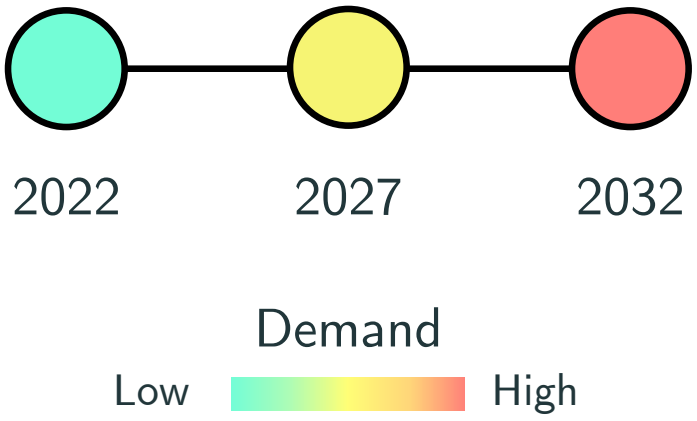
- minimise the total expected cost of expansion over a given time horizon, while maintaining a specified level of reliability; and
- account for uncertainty in future demand for electricity.

Model Components



Scenarios

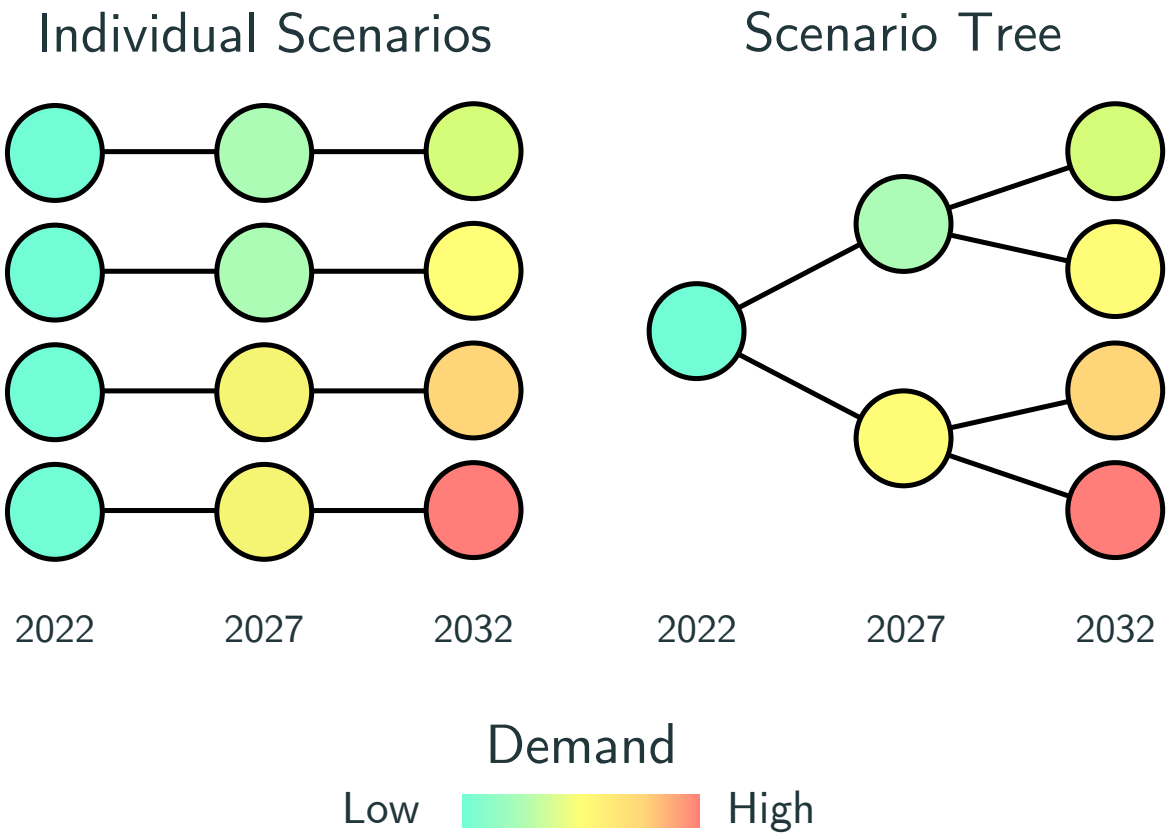
We discretise the planning horizon into a sequence of stages, with varying levels of demand, at which decisions can be made.



We aim to find an optimal expansion plan over the whole planning horizon, such that at each stage there is an operating configuration that keeps the SAIDI of the network below a specified level.

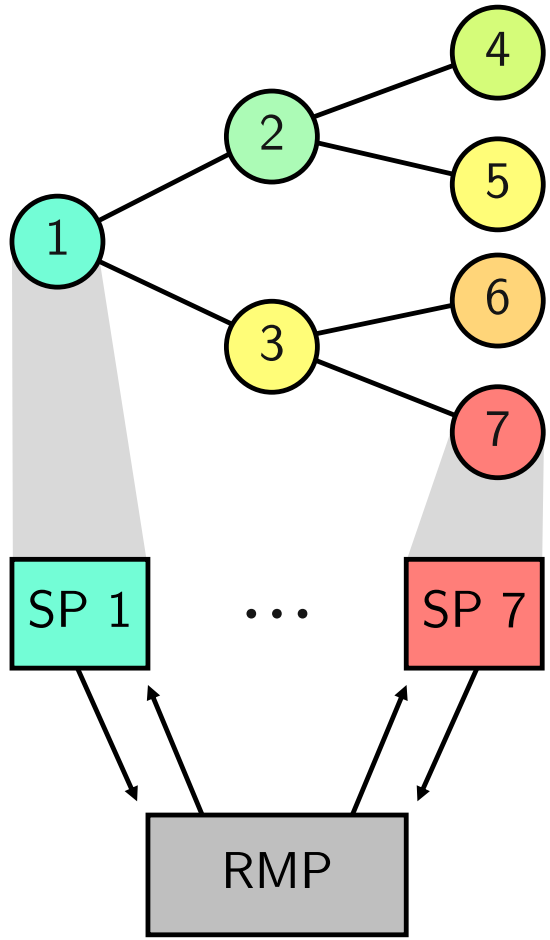
Scenario Trees

In practice, it is common to consider a range of scenarios with varying levels of demand. We can combine these into a scenario tree.



Solution Method: Decomposition Framework

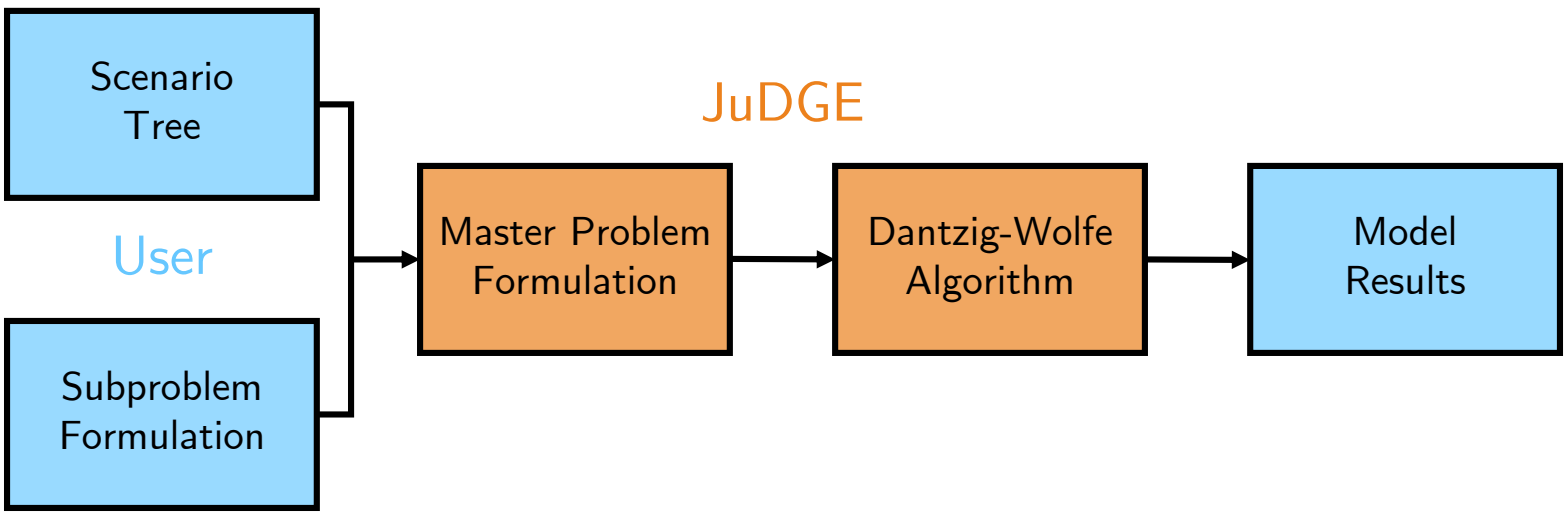
As the size of the problem grows, the resulting model becomes large and a form of decomposition is often needed to solve it. We use Dantzig-Wolfe decomposition[1].



[1] Singh, Philpott, and Wood (2009). *Dantzig-Wolfe Decomposition for Solving Multistage Stochastic Capacity Planning Problems.*

Solution Method: JuDGE

JuDGE[1] is an open-source Julia package developed by EPOC that implements this decomposition[2].

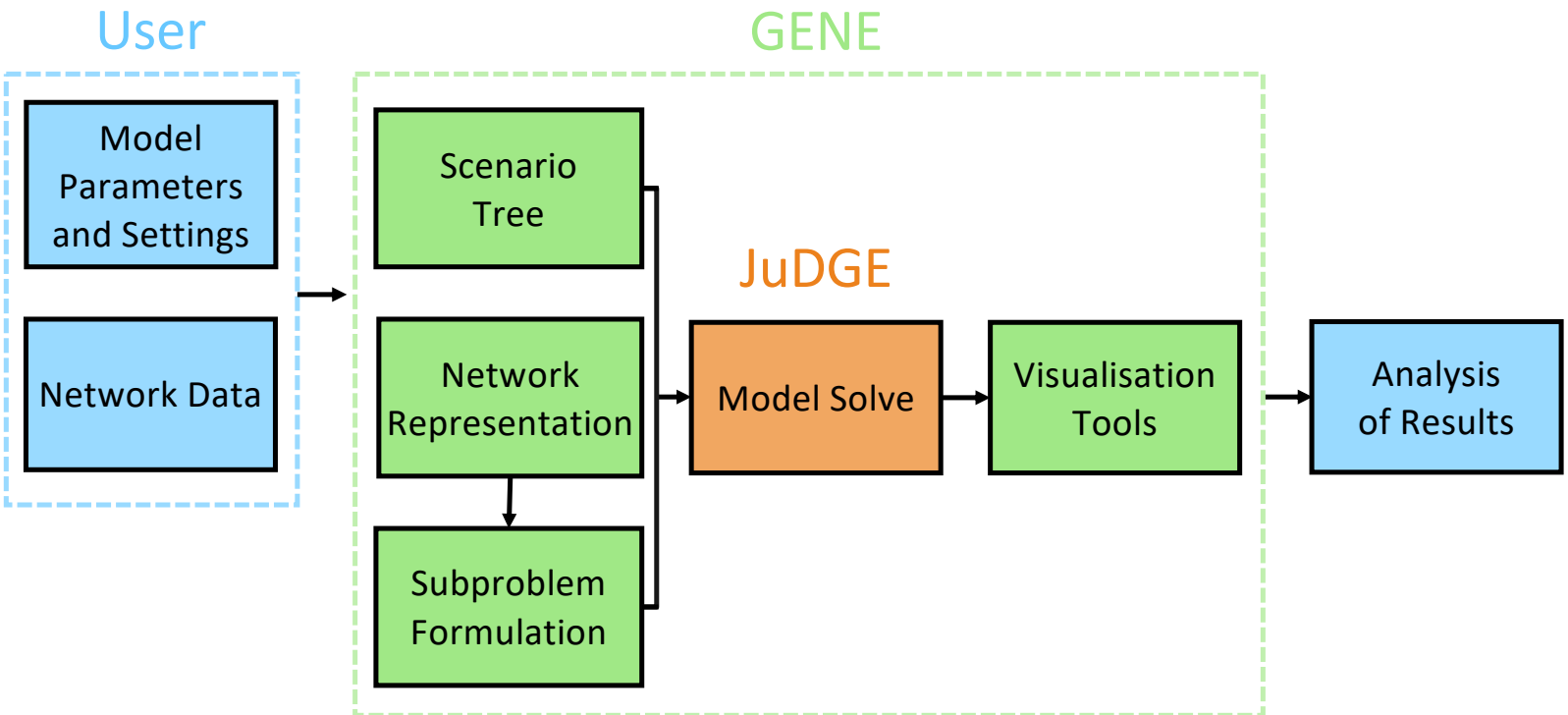


[1] JuDGE Website: github.com/EPOC-NZ/JuDGE.jl.

[2] Downward, Baucke, and Philpott (2020). *JuDGE.jl: a Julia package for optimizing capacity expansion.*

GENE: Overview

We have implemented our model called GENE (Generalised Electricity Network Expansion).



GENE: Network Data

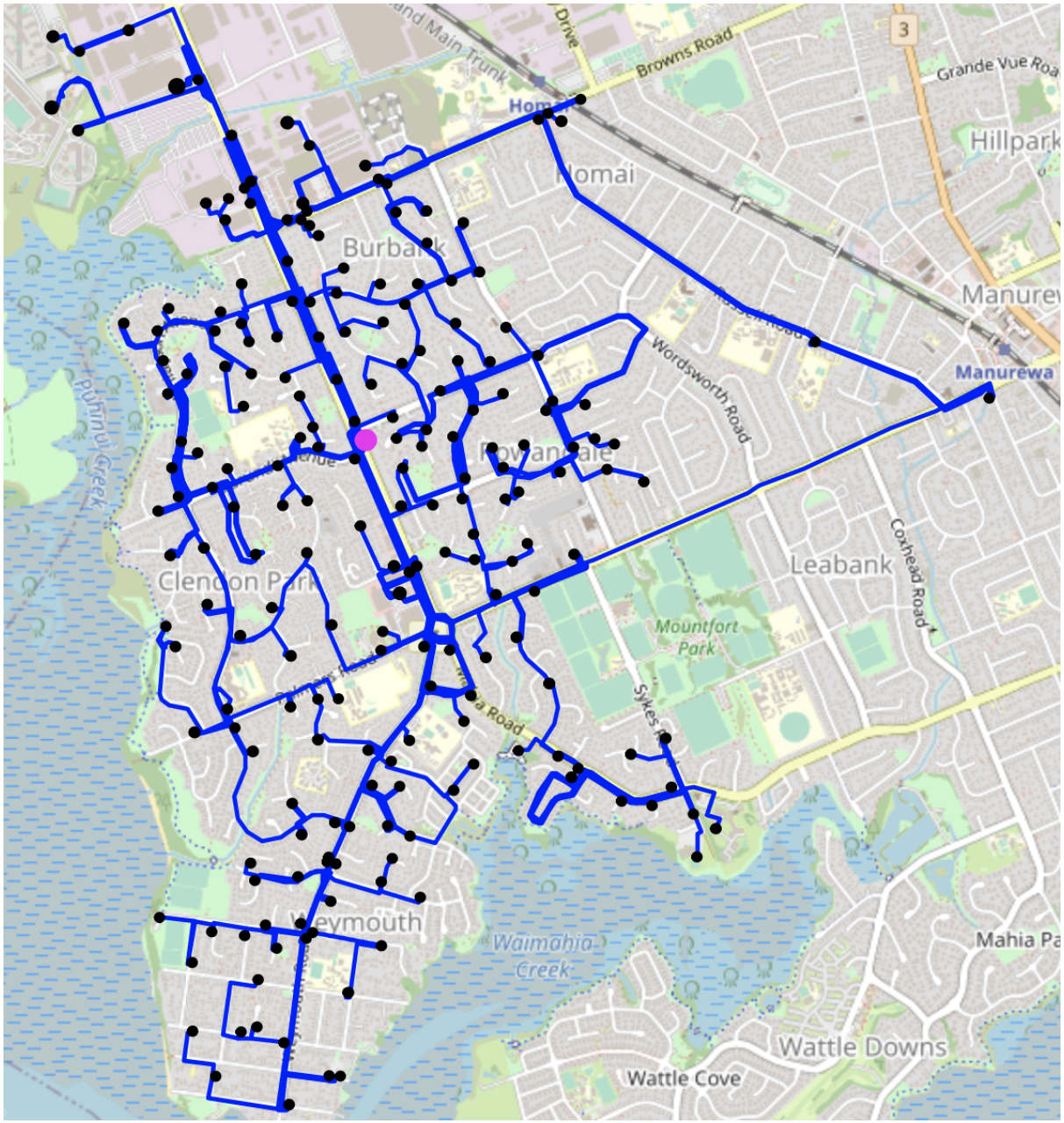
	A	B	C	D	E	F	G	H
1	**Node ID**	**Name**	**Latitude**	**Longitude**	**Current Peak Demand (kW)**	**Current ICPs**	**GXP**	**Batteries**
2	1	Substation	-37.036	174.866	0	0	1	0
3	2	S-1241 Jack Rd No5	-37.012	174.866	9.87	20	0	0
4	3	S-3128 Jack Rd No6	-37.045	174.868	10.93	22	0	0
5	4	S-2267 Milton Pl	-37.039	174.868	13.42	27	0	1
6	5	S-2145 Cliff Dr No1	-37.039	174.867	31.51	63	0	0
7	6	S-2363 Cliff Dr No2	-37.041	174.869	24.23	48	0	0
8	7	S-2523 Mountain Pl	-37.042	174.865	12.88	26	0	1
9								
10								
11								
12								
13								
14								

Case Study: Clendon Distribution Network

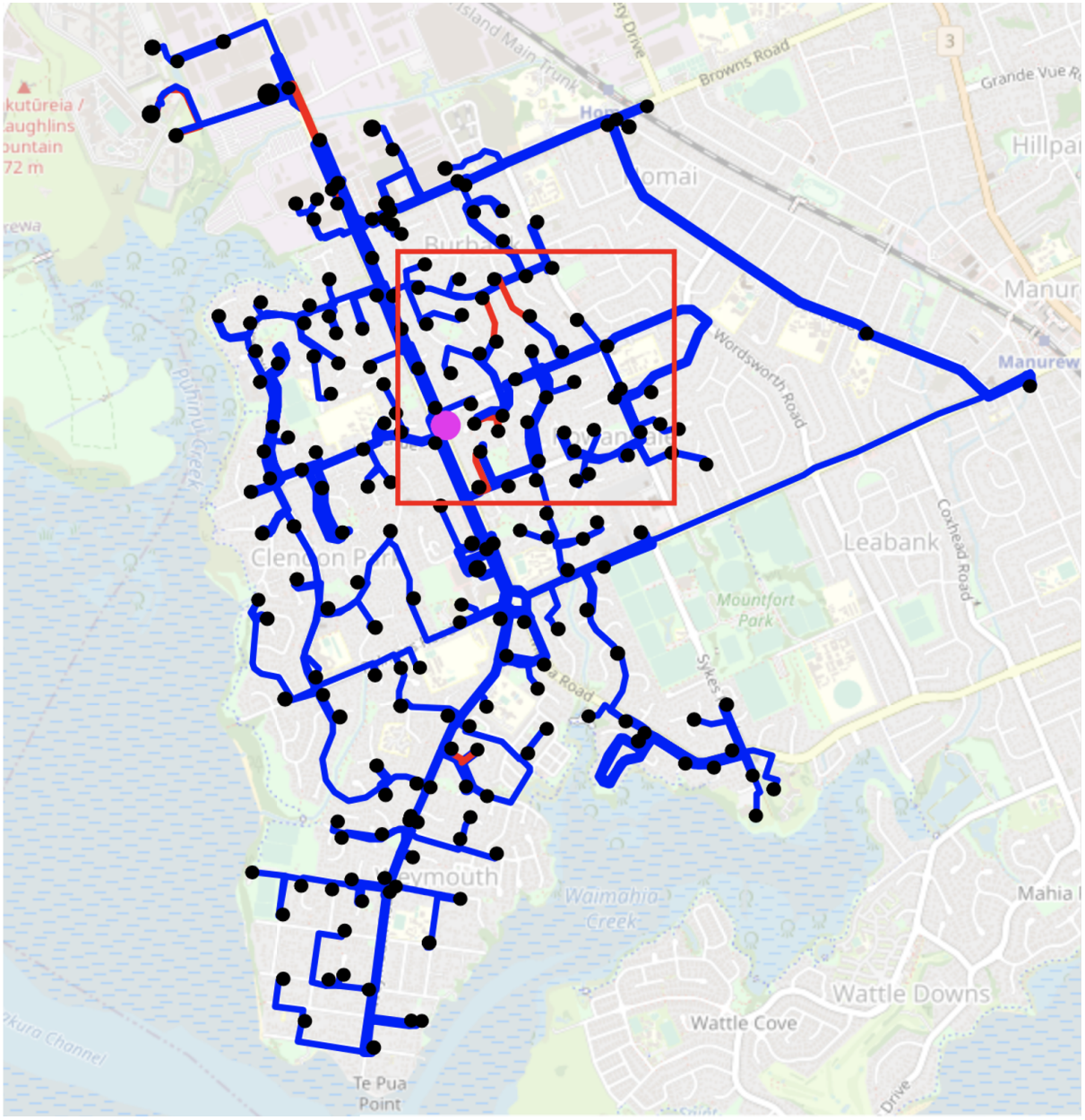
We have used GENE to investigate the Clendon distribution network over a 20 year planning horizon with eight demand scenarios. We have investigated

- how batteries can be used to delay line expansions; and
- how different SAIDI tolerances influence network upgrades.

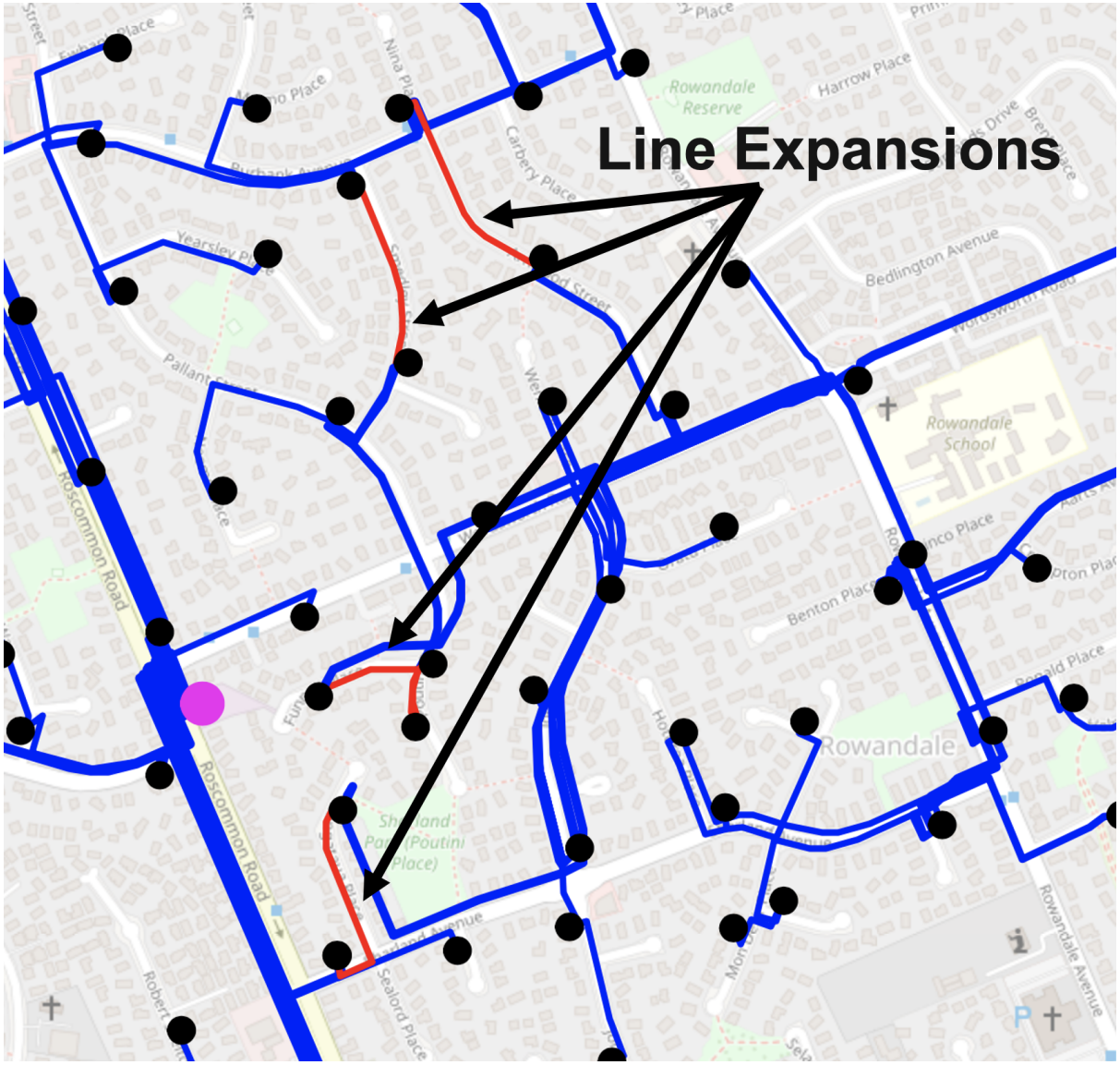
Clendon Distribution Network



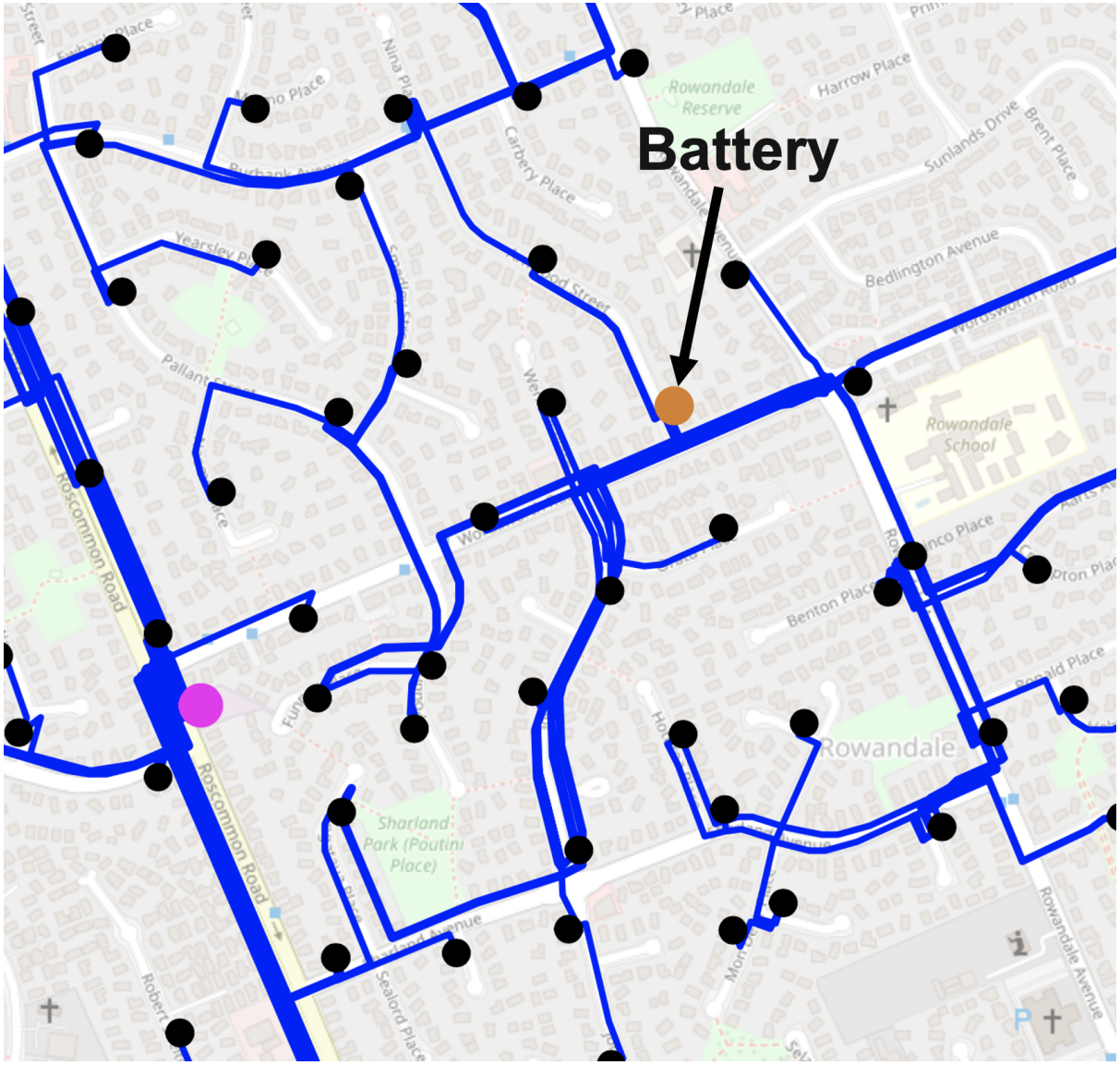
Utility of Batteries



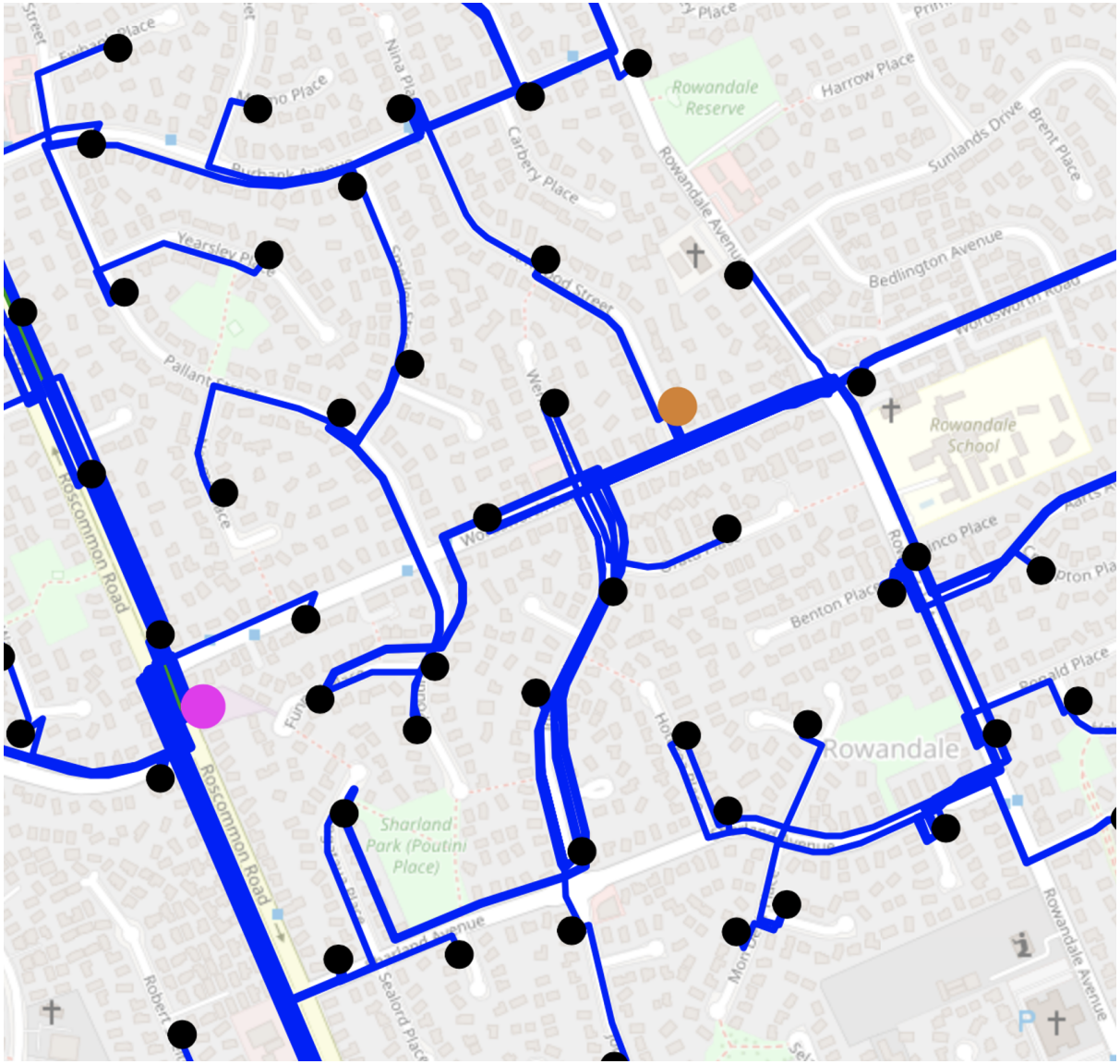
Present Day Plan: No Batteries



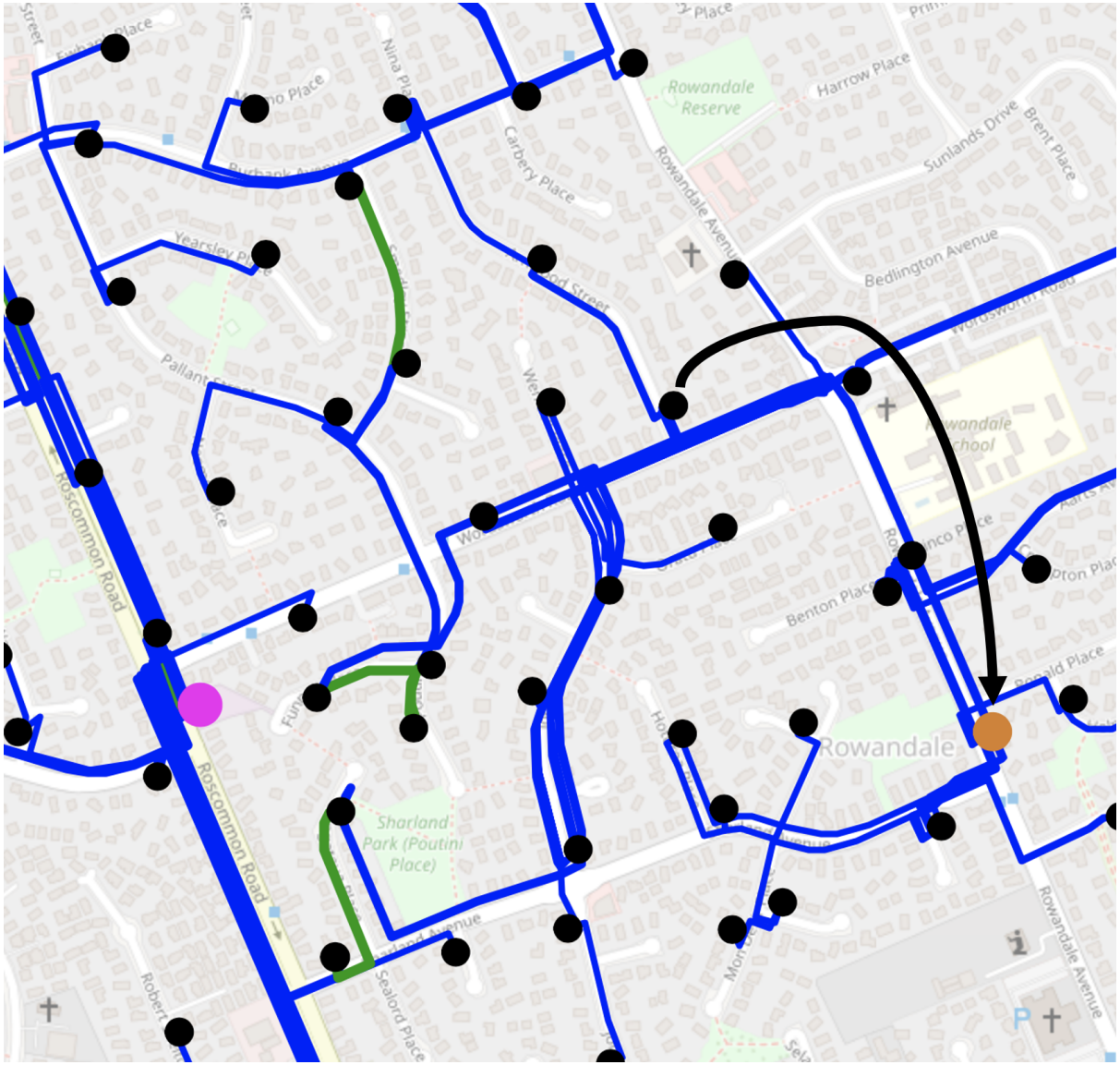
Present Day Plan: One Battery



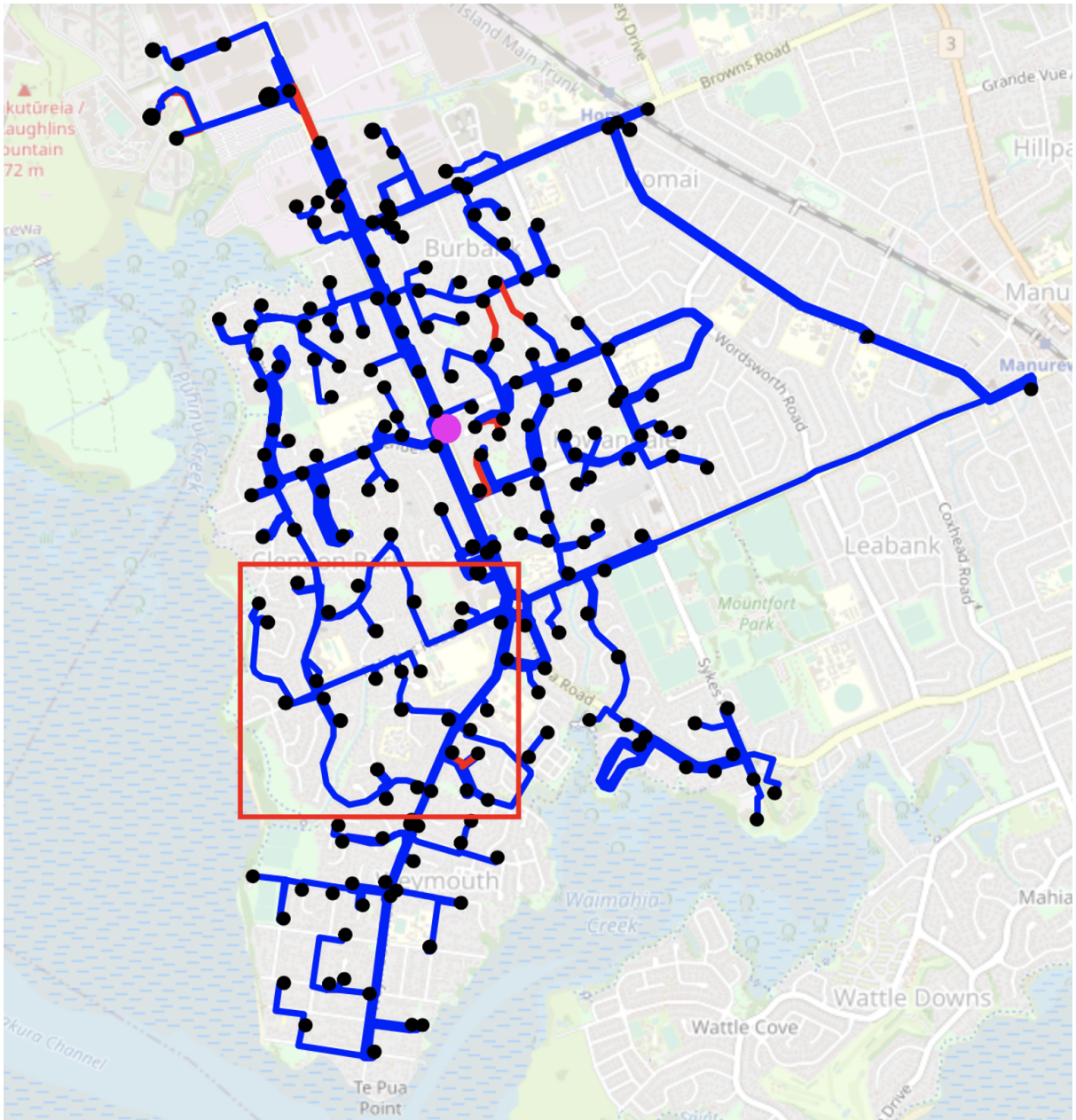
10 Years Later: Low Growth



10 Years Later: High Growth

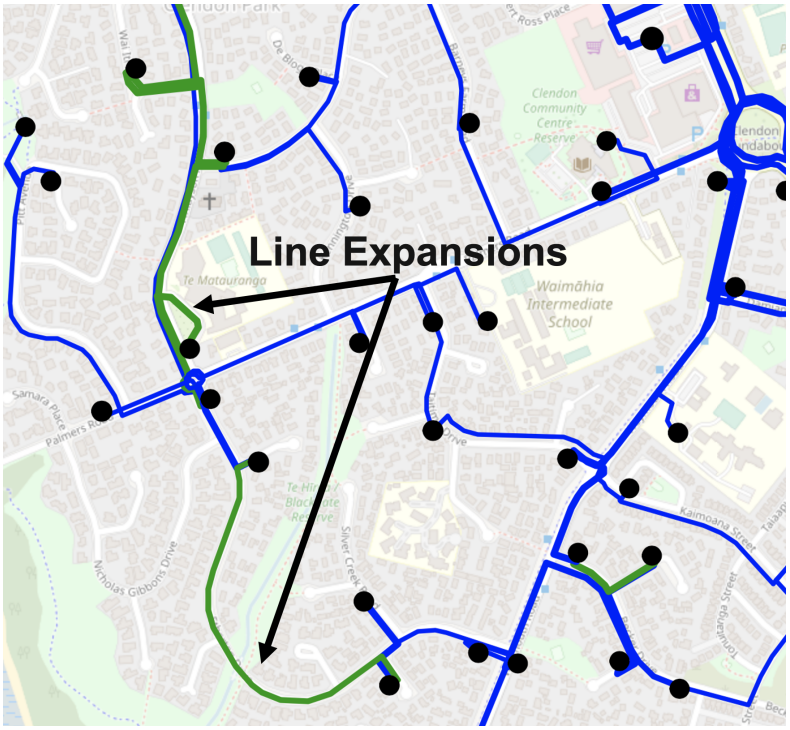


Different SAIDI Tolerances

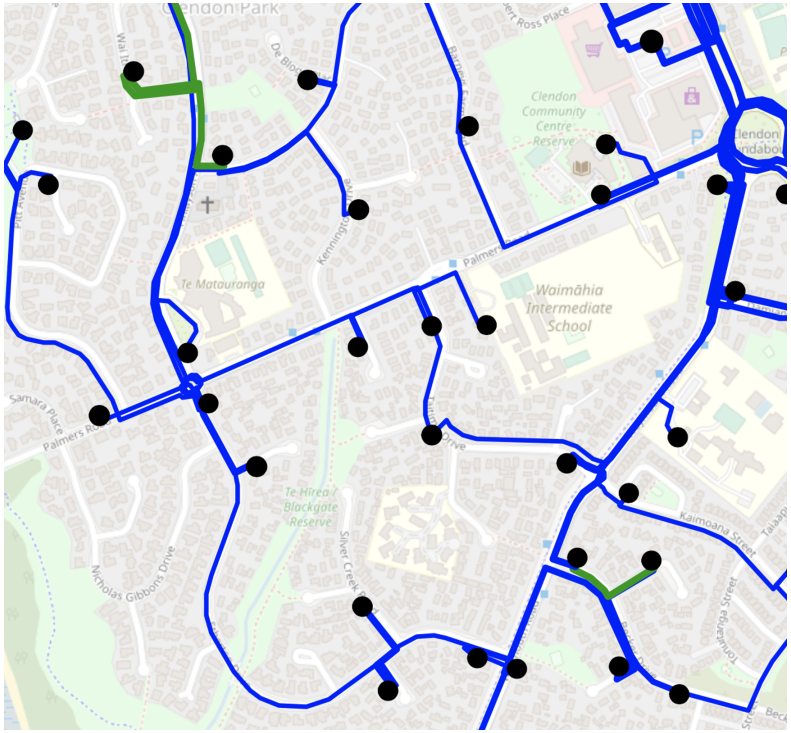


Southern Network Reinforcement

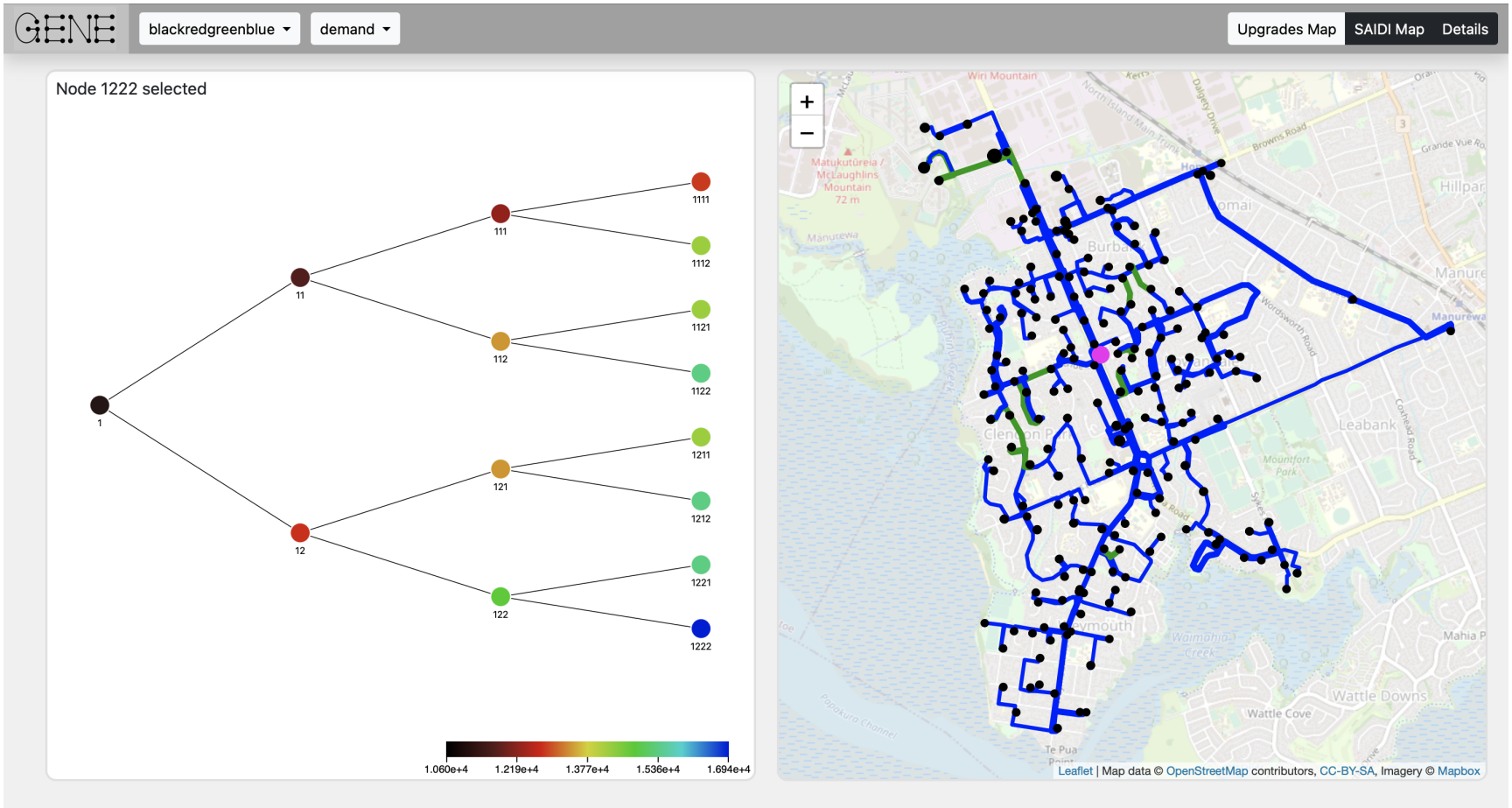
Low SAIDI (More Reliable)



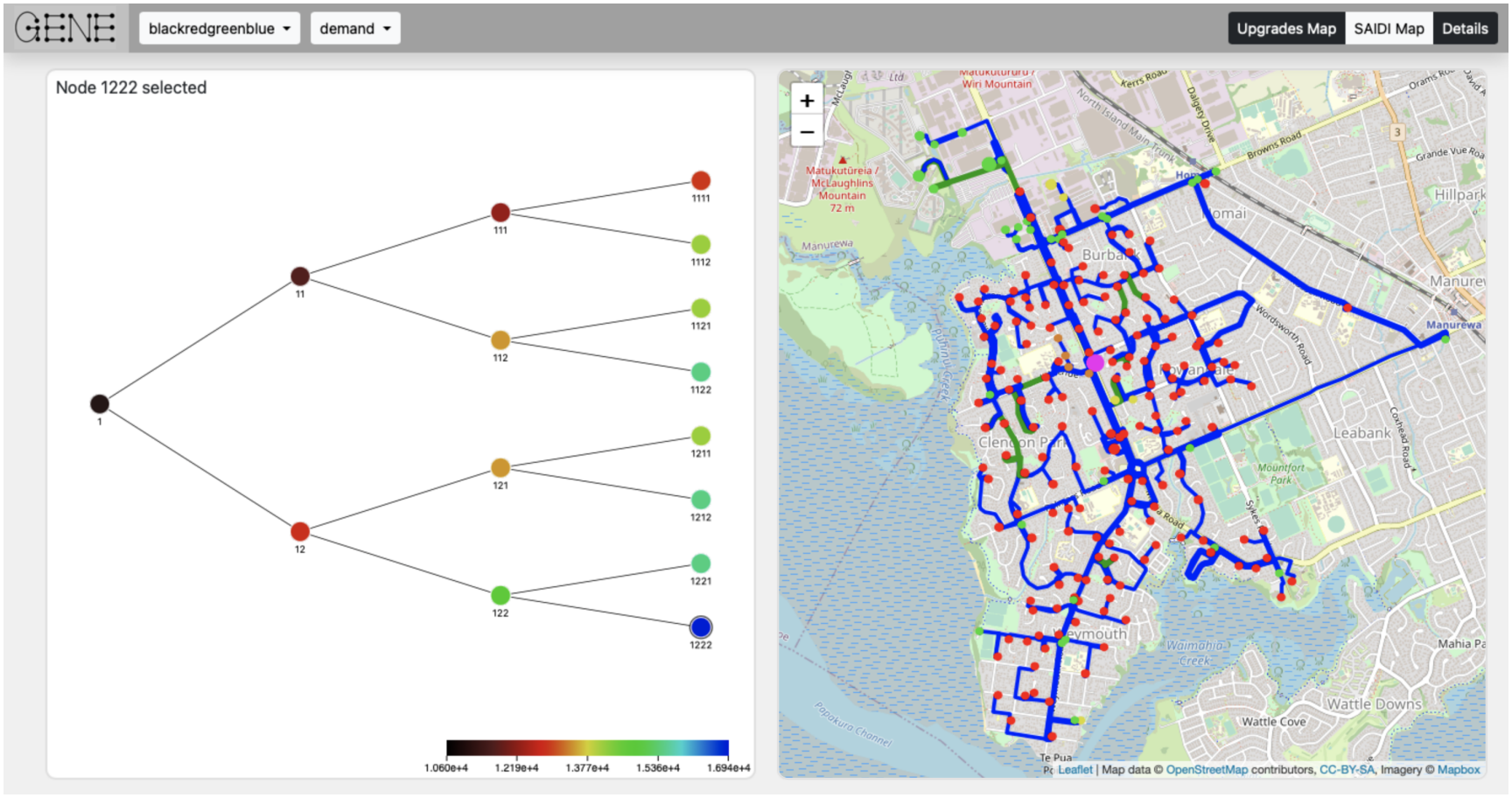
High SAIDI (Less Reliable)



Visualisation Tool: Upgrades Map



Visualisation Tool: SAIDI Map



Summary

Today we have

- discussed the components used to model capacity expansion problems for an electricity distribution network under uncertainty in demand;
- described how GENE aims to minimise investment cost while maintaining a given level of network reliability; and
- demonstrated how GENE can be used to investigate the timing and location of investments.

References

- Vector (2021). *Vector Electricity Asset Management Plan 2021–2031*. URL: vector.co.nz/about-us/regulatory/disclosures-electricity/asset-management-plan.

- Singh, K. J., Philpott, A. B., and Wood, R. K. (2009). *Dantzig-Wolfe decomposition for solving multistage stochastic capacity-planning problems*. Operations Research, 57(5), 1271-1286.

- JuDGE Website: `github.com/EPOC-NZ/JuDGE.jl`.

- Downward, A., Baucke, R. and Philpott, A.B. (2020). *JuDGE.jl: a Julia package for optimizing capacity expansion*. Technical report, Engineering Science, University of Auckland, 2020. URL: http://www.optimization-online.org/DB_FILE/2020/11/8086.pdf.