Broome Clean Energy Study

Decarbonising the regions

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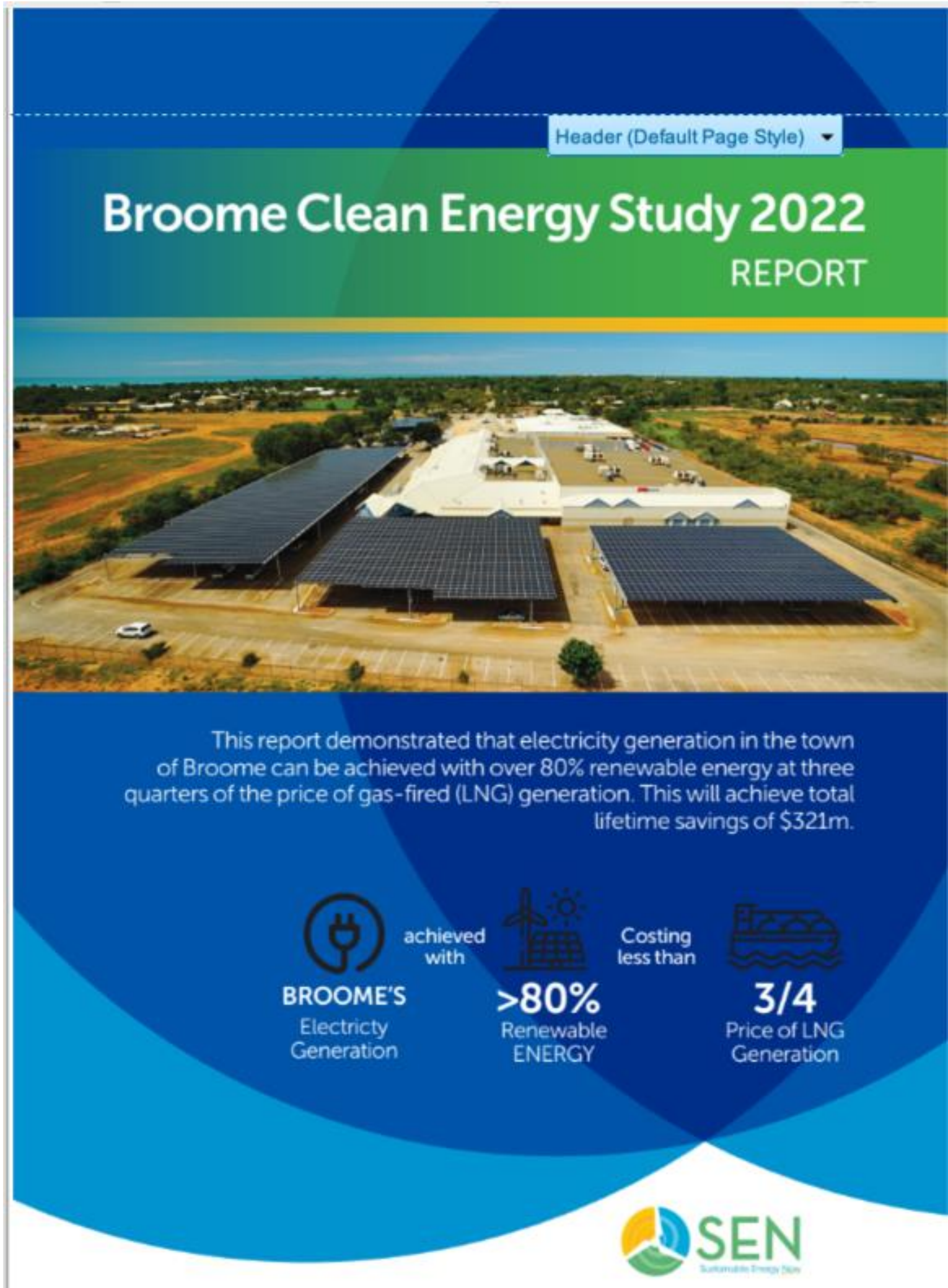
Acknowledgements
Whadjuk Noongar Boodjar



Broome Clean Energy Study

- Following up on the 2018 Kimberley Clean Energy Roadmap
- Launch of Powermatch, our powerful new modelling tool
- Broader application in SEN’s SWIS Decarbonisation Campaign

- Commissioned by Environs Kimberley and the Lock the Gate Alliance
- Project work in 2022

Key Finding

Electricity generation in Broome can be achieved with

- over 80% renewable energy
- at three quarters of the price of gas-fired (LNG) generation

Total lifetime savings of $321m

Outline

Introduction

Background

Modelling

Results

Implementation

Energy Transition

Conclusion

Policy Environment

- WA Climate Change Policy
- Sectoral Emissions Reduction Strategy
- Climate Change Legislation - later in 2023
    - reduce Gov’t emissions by 80 per cent below 2020 levels by 2030

Broome

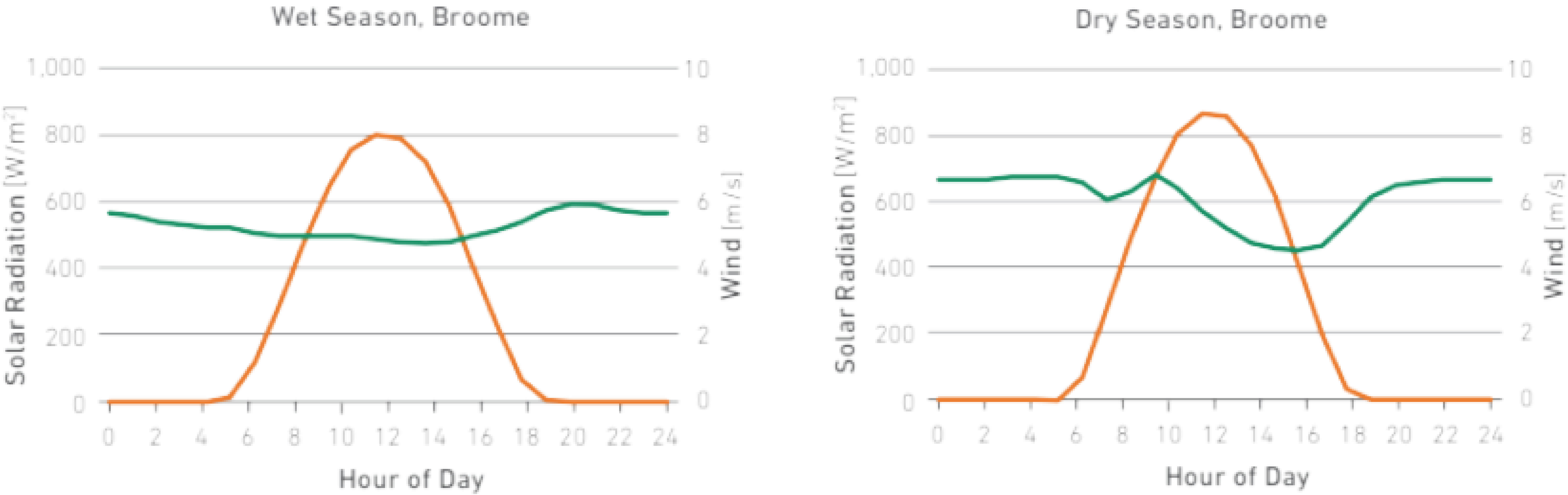
Context

- Population ~14,500, increasing in Dry Season
- Stand-alone ‘macro grid’
- 40MW of LNG-fuelled generators
- 8.3 MW of rooftop solar - constrained
- Current supply contract expires 2027
    - We’ve modelled for 2024 to give time for planning/construction

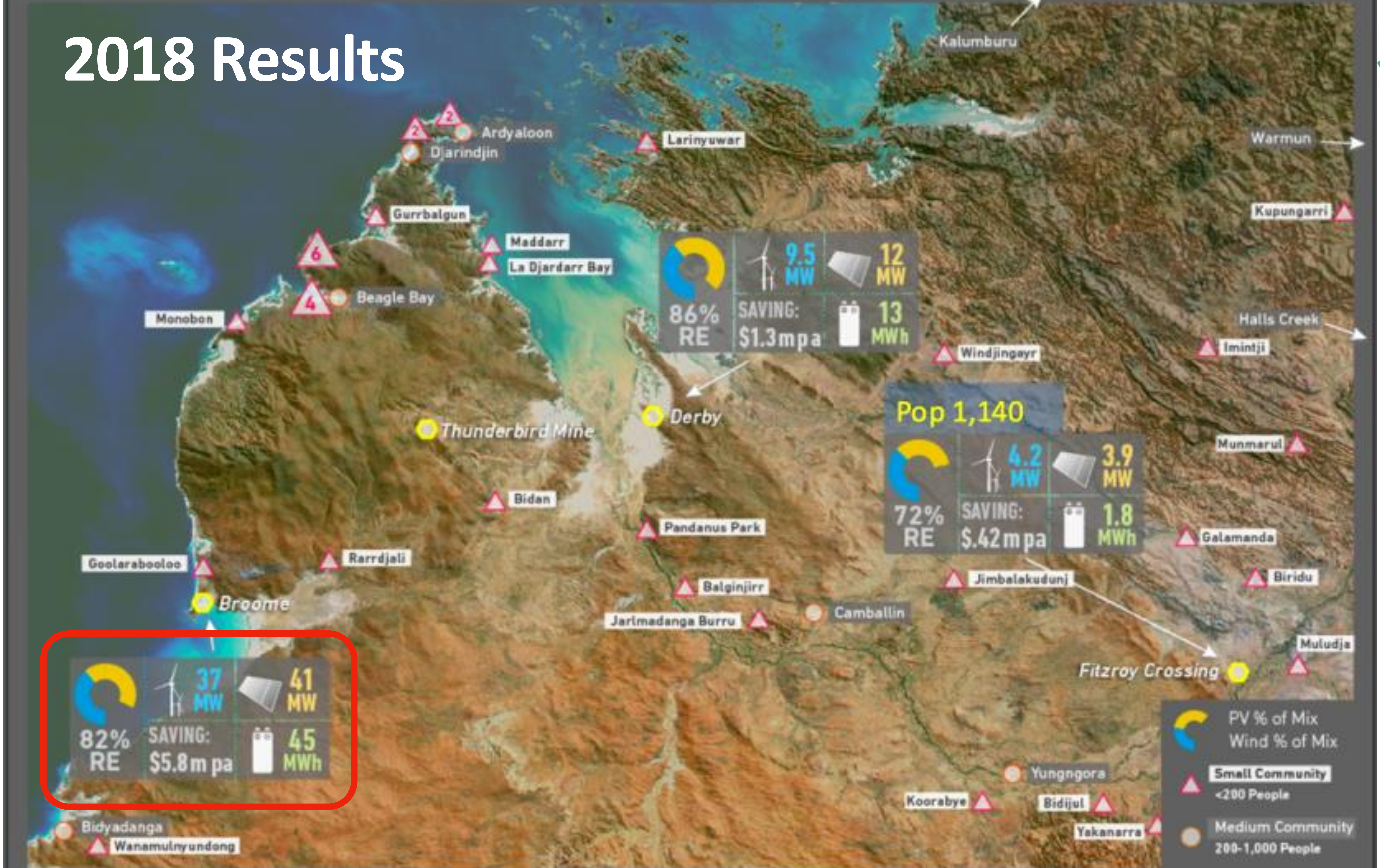
Weather Factors in Broome

Weather patterns - not much wind

Cyclone risk relatively low



2018 Results



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Horizon Power Initiatives

since 2018

- Community batteries in Broome - 1.1 MWh
  - Extra rooftop PV
- Distributed Energy Resources Managem… …stem (DERMS) technology
  - completely feasible to achieve … …netration of PV
- "Our goal is that all Horizon … households can have access to rooftop solar by 2025"
- 100% RE possible - … decade - ABC Radio interview

Some progress but not enough

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Technical Terms

Energy capacities

- Generation technologies have capacities in Megawatts (MW)
- Batteries have capacities in Megawatt hours (MWh)
- Batteries have varying discharge times (1, 2, 4, 8 hours)
- A 40 MWh hour battery can deliver 10 MW of electricity for 4 hours
- Our modelling showed that 4 hour batteries were slightly better than 8 hour batteries

Modelling Background

Modelling is only as good as its assumptions

- Real world costs are ‘Commercial in Confidence’
- Reputable Australian cost estimates based on real projects
  - Capital expenditure - CAPEX
  - Operational expenditure - OPEX
    - Fixed and Variable OPEX
- Scaled by remoteness factor and weather factor
- Levelised Cost of Energy

Levelised Cost of Energy

Allows comparison

Average total cost to build and operate a power-generating asset

- **CAPEX + OPEX**

over its lifetime **(10-25 years)**

divided by the total lifetime energy output **(E_Y)**

$$LCOE_{Tech} = (CAPEX + OPEX_{fixed}) / E_y + OPEX_{Variable} + OPEX_{Fuel}$$

Technology Costs

Assumptions needed

- Annual ‘Gencost’ report (CSIRO and AEMO)
  - Projected over 10 years
- Weighted Average Cost of Capital - 7.5%
- Carbon emissions per technology

Cost Assumptions

- Used 2024 technology costs
  - Broome contract expires in 2027
- Wind costs higher than 2018
  - recent publication with ‘regional factors’ pushed costs up
- Battery costs much lower than 2018
- Solar about the same

Carbon Price

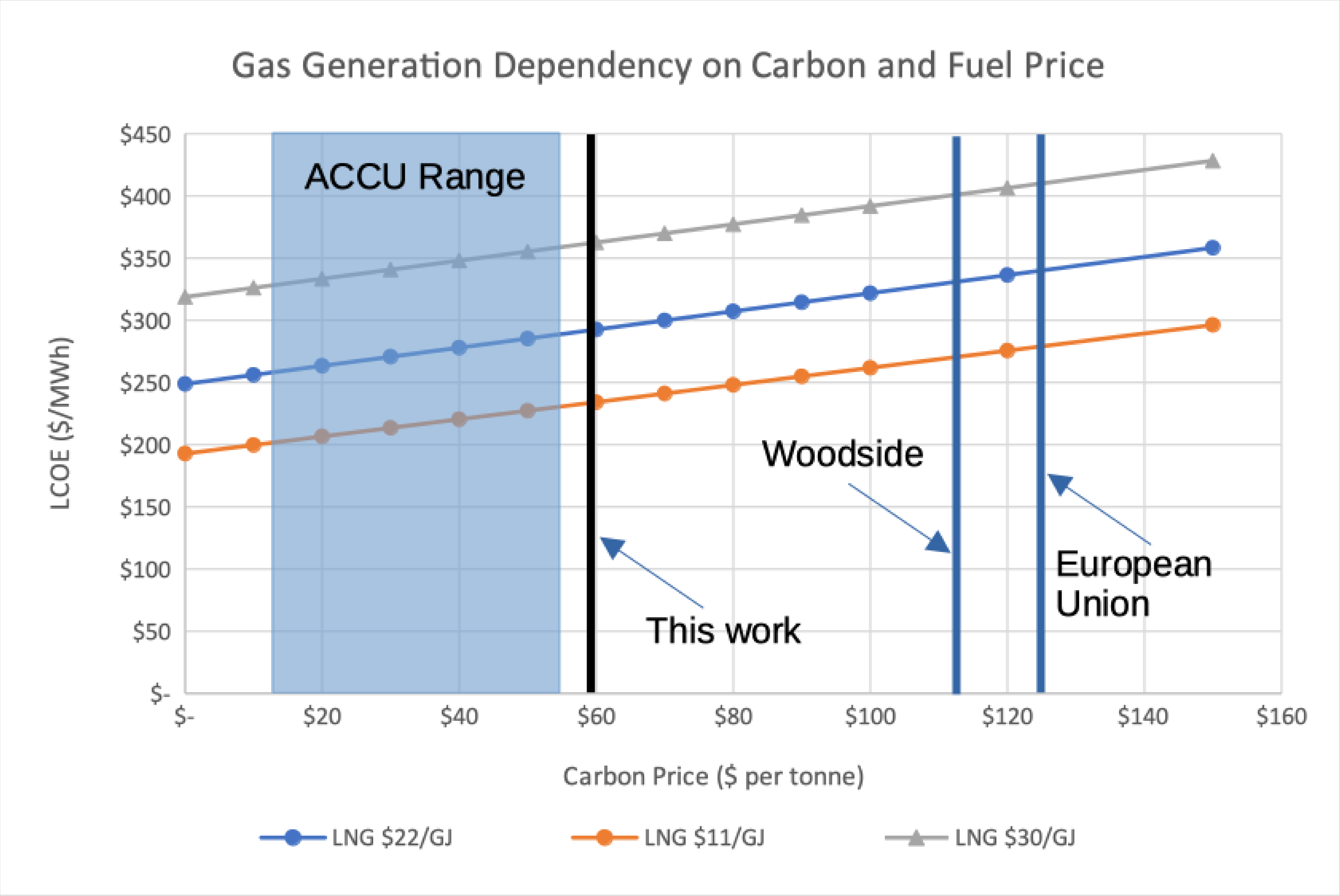
$60 per tonne

Australian Carbon Credit Units

- **ACCU**

Done before change of government

2023 ACCU cap $75



SEN's Modelling Tools

SIREN - Powermatch

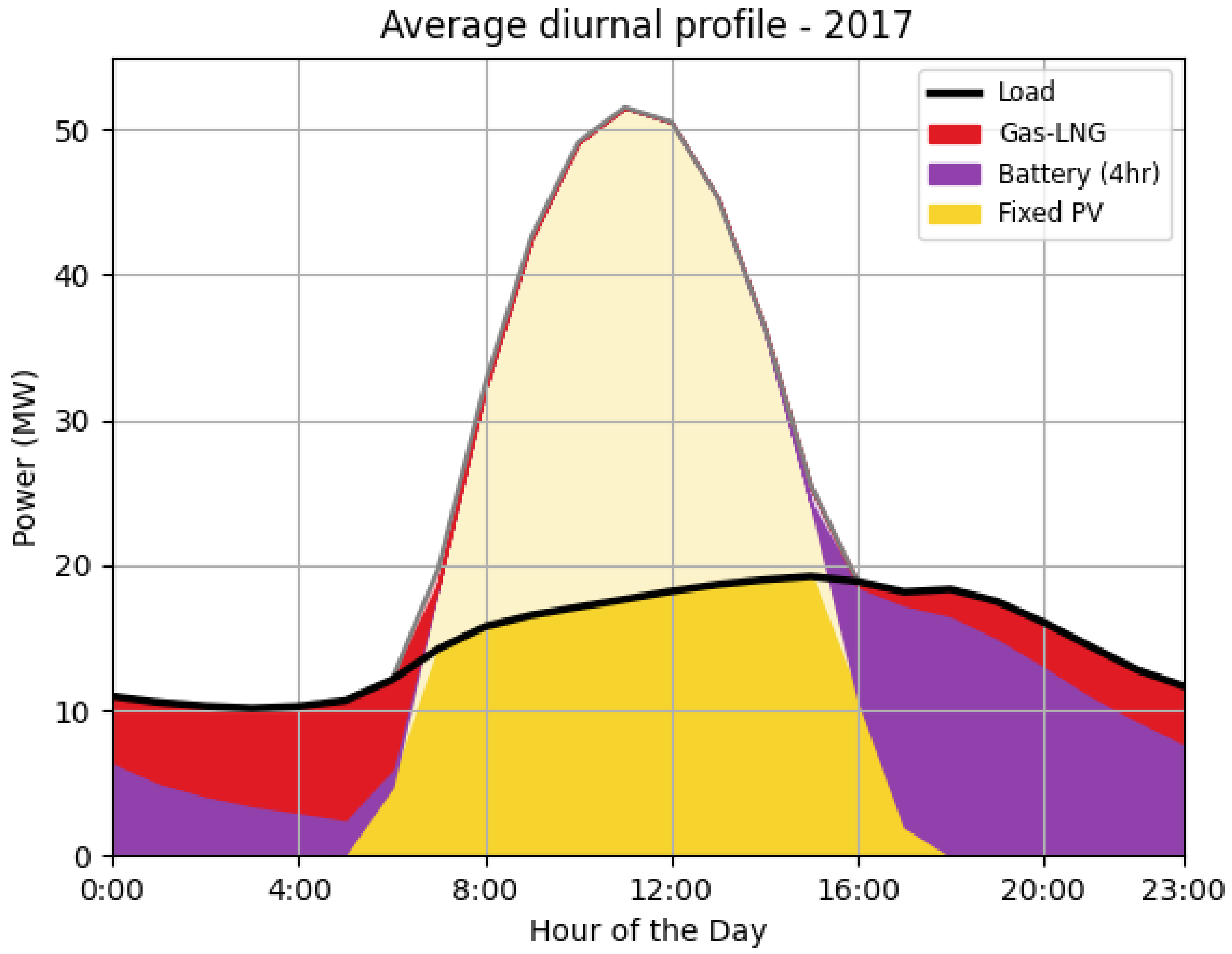
SIREN needs:

- Load Profile
- Technology parameters (PV, Wind)
- Weather data

Model generation plants to meet the load profile

Outputs

- modelled load profile and surpluses and shortfalls
- 8760 hours in a year



Powermatch

Evolution of old spreadsheet approach - much more powerful

Meets shortfalls by

- Scaling technologies
- Adding storage
- Minimising costs

Powerful ‘genetic’ modelling system

Once optimised, we can do ‘batch’ calculations to identify trends

Technology		Load	Onshore Wind	Rooftop PV
Hour	Period	Hourly (MWh)	Hourly Gen (MWh)	Hourly Gen (MWh)
1	2017-01-01 0(	12.864	72.33	0.000
2	2017-01-01 0	12.554	73.64	0.000
3	2017-01-01 0	12.265	70.50	0.000
4	2017-01-01 0	12.125	61.30	0.000
5	2017-01-01 0	12.037	46.56	0.000
6	2017-01-01 0	11.702	43.12	3.876
7	2017-01-01 0	12.226	34.85	21.531
8	2017-01-01 0	13.638	34.61	58.715
9	2017-01-01 0	15.134	32.39	99.087
10	2017-01-01 0	16.456	27.79	128.149
11	2017-01-01 1	17.236	26.06	148.361
12	2017-01-01 1	17.699	24.70	157.373
13	2017-01-01 1	18.019	22.38	154.306
14	2017-01-01 1	18.341	19.39	140.776
15	2017-01-01 1	18.521	16.69	116.322
16	2017-01-01 1	18.798	14.86	82.635
17	2017-01-01 1	18.599	13.98	42.310
18	2017-01-01 1	18.047	14.39	7.825
19	2017-01-01 1	17.511	17.73	0.077
20	2017-01-01 1	17.579	21.83	0.000
21	2017-01-01 2	16.623	27.74	0.000
22	2017-01-01 2	15.337	32.13	0.000
23	2017-01-01 2	14.020	28.59	0.000
24	2017-01-01 2	12.855	18.85	0.000

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Modelling

Three scenarios

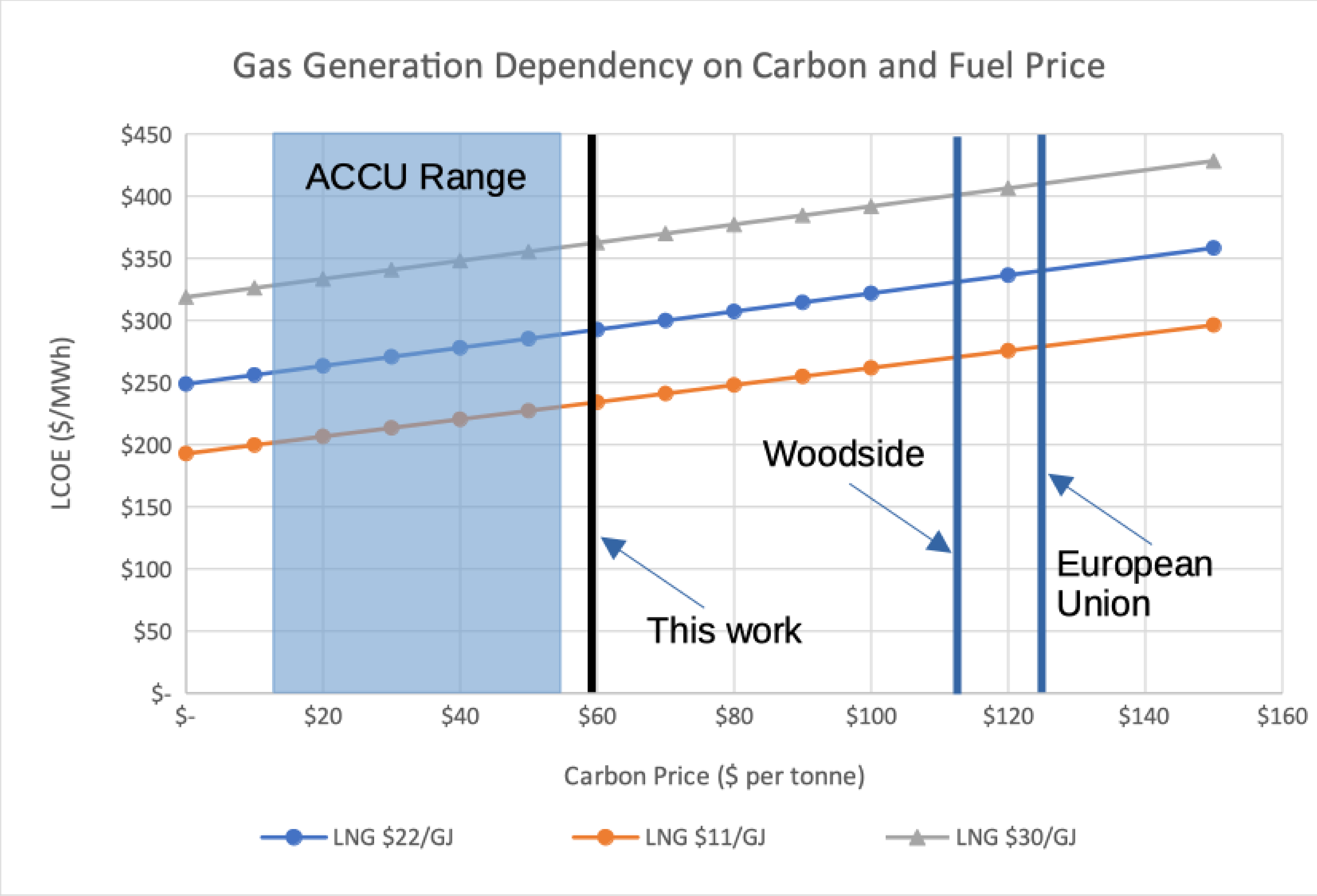
- Existing gas-fuelled generation
- PV and battery
- Wind, PV and Battery

LNG-only Generation

Broome - $22/ GJ

- Road trains from Karratha

- Federal gas cap
- $12/ GJ



PV and Battery

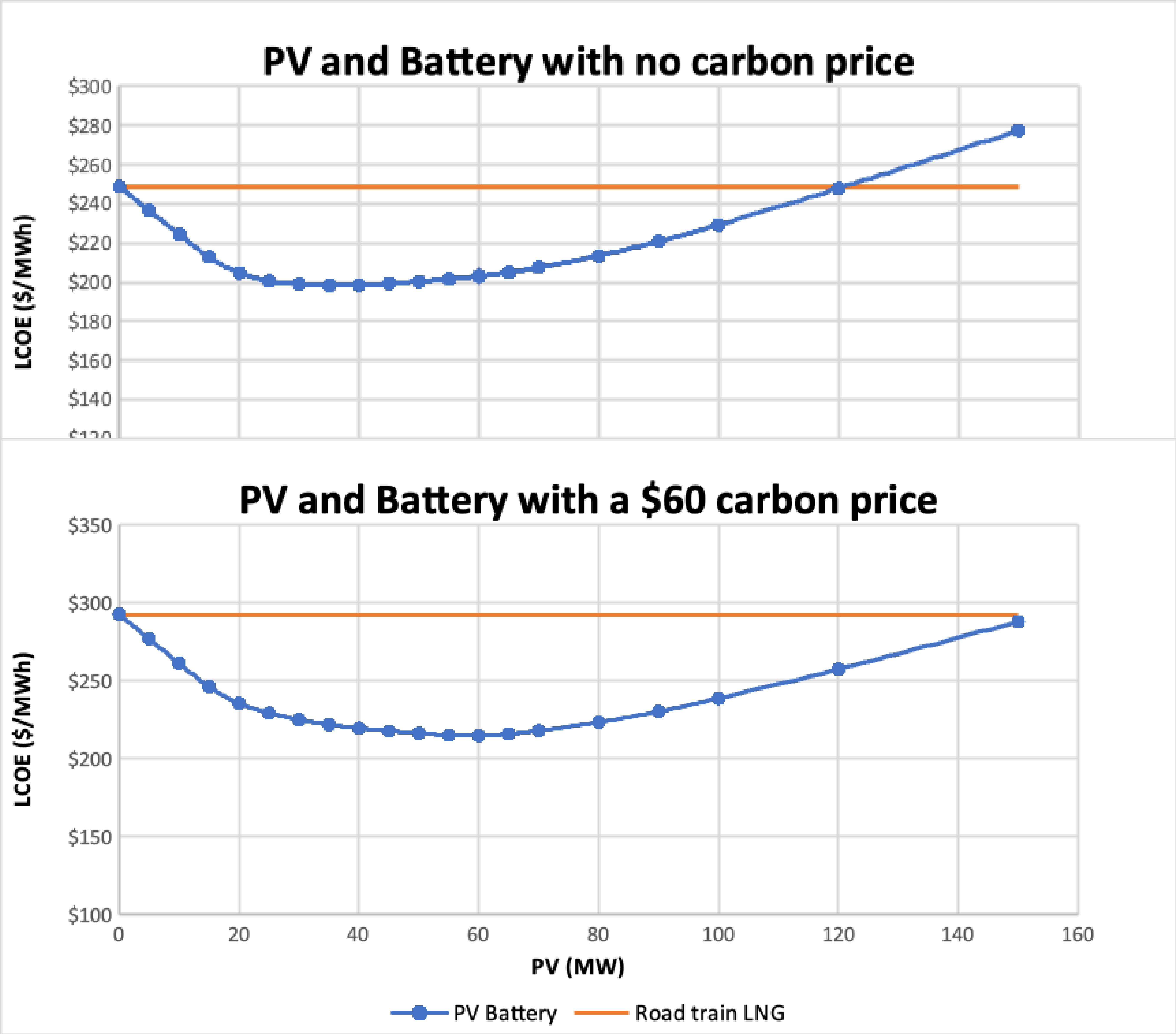
Overview Results

No Carbon Price

- Flat minimum at 80% of LNG cost

$60 Carbon price

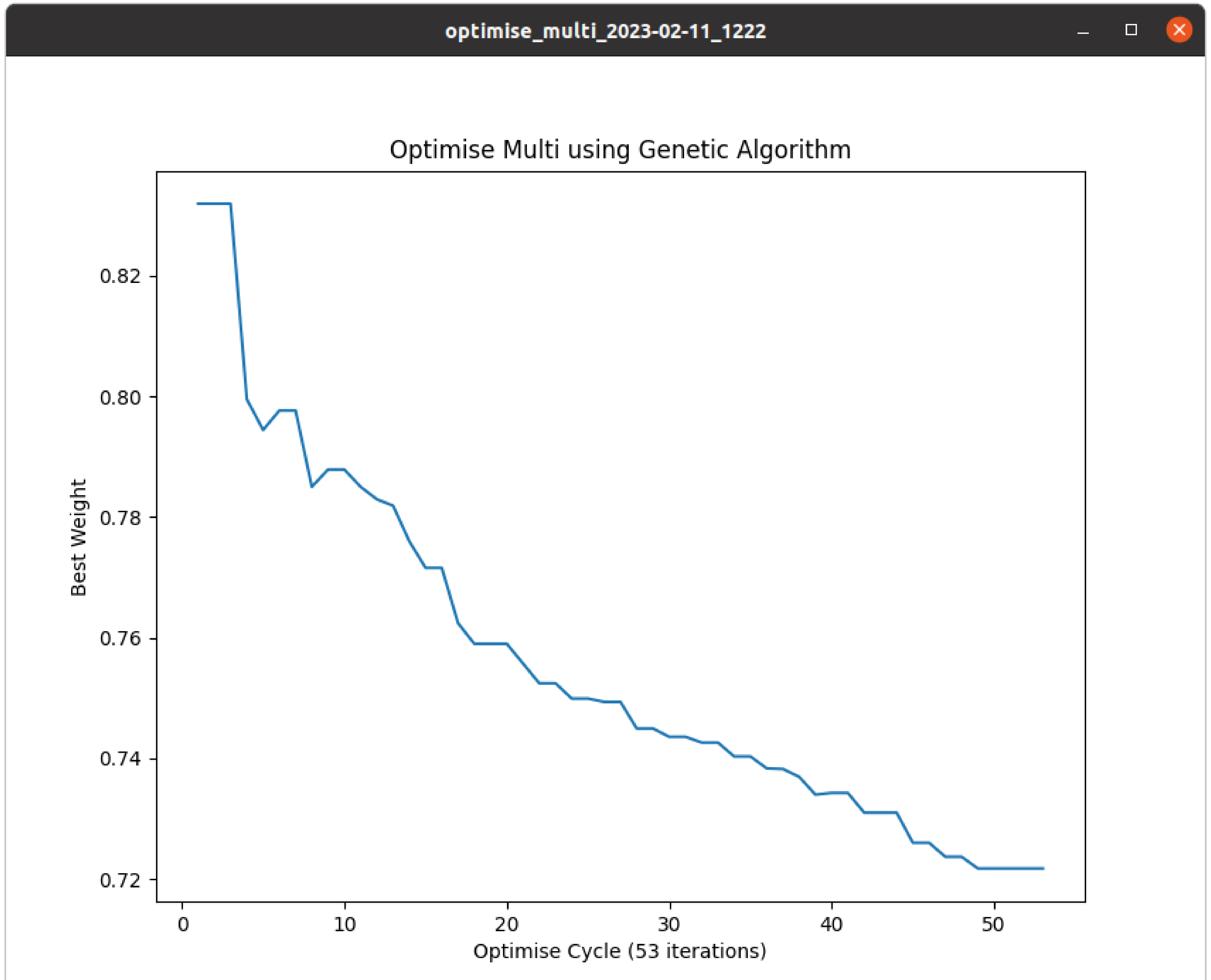
- 73% of LNG cost
- $78 /MWh less than LNG



How did we achieve this?

Genetic optimisation

- Mutate the 'population'
- Find the best mutation
- Repeat until no change



Choose Optimal Generator Mix

Facility	Lowest Weight	Your pick
Onshore Wind	12.6 MW	12.6 MW
Rooftop PV	0.0 MW	0.0 MW
Fixed PV	25.0 MW	25.0 MW
Battery (4hr)	37.0 MWh	37.0 MWh
Gas-LNG	24.0 MW	24.0 MW
Load%	*99%*	*99%*
RE%	*61%*	*61%*
LCOE	*$192.60*	*$192.60*
CO2	*44.8K*	*44.8K*
Surplus%	*3%*	*3%*
Cost	*$25.2M*	*$25.2M*
Quit	Lowest Weight	Your pick

SIREN - Add to Batch

Press 'Yes' to add to Batch file

No Yes

Collating Results

Add results to 'batch' file

For each 'Run'

- Add results to 'batch' file
- Easy comparison of results

Weaknesses

- May be false minima
- Can't see trends
- Less LNG than installed

	B4-25	B4-25	B4-50	B4-50	B4-100
Model Label	05-12 17:32	05-12 17:37	05-12 17:34	05-12 17:35	05-12 17:38
Capacity (MW)	**MW**	**MW**	**MW**	**MW**	**MW**
Onshore Wind					
Fixed PV	52.00	28.00	30.00	29.00	38.00
Battery (4hr)	25.00	24.00	48.00	40.00	94.00
Battery (8hr)					
Gas-LNG	24.00	24.00	24.00	26.00	24.00
Total	101.00	76.00	102.00	95.00	156.00
Carbon Price	60.00	60.00	60.00	60.00	60.00

Batch Modelling

Run a series of models around the optimised minimum

- Explore trends
- Choose a fixed amount of PV (10-150MW)
- Vary the amount of battery needed (26 increments)
- 520 permutations
- Semi-automatically identify best solution for each amount of PV

	A	B	C	D
1			B25 PV25	B25 PV30
2	Model Label	start	05-10 18:27	05-10 18:29
3	Capacity (MW/MWh)		MW	MW
4	Onshore Wind			
5	Fixed PV		23.00	28.00
6	Battery (4hr)		25.00	23.00
7	Battery (8hr)			
8	Gas-LNG	30.00	24.00	24.00
9	Total	30.00	72.00	75.00
10				
11	LCOE ($/MWh)			
12	Onshore Wind			
13	Fixed PV		61.86	61.86
14	Battery (4hr)		320.26	218.95
15	Battery (8hr)			
16	Gas-LNG	248.70	261.32	265.97
17	Total	248.70	193.14	181.30
18	Adjusted LCOE	248.70	196.18	191.12
19				
20	Carbon			
21	Carbon Price	60.00	60.00	60.00
22	Carbon Cost	5,737,800	3,579,681	3,312,529
23	LCOE (incl. CO2)	292.50	223.50	216.41
24				
25	RE			
26	RE %age	0.0%	34.9%	38.6%
27	Storage %age		2.9%	3.8%
28	RE %age of Total Load	0.0%	37.7%	42.4%
29				
30	Emissions (tCO2e)			
31	Onshore Wind			
32	Fixed PV			
33	Battery (4hr)		124	166
34	Battery (8hr)			
35	Gas-LNG	95,630	59,538	55,042
36	Total	95,630	59,661	55,209

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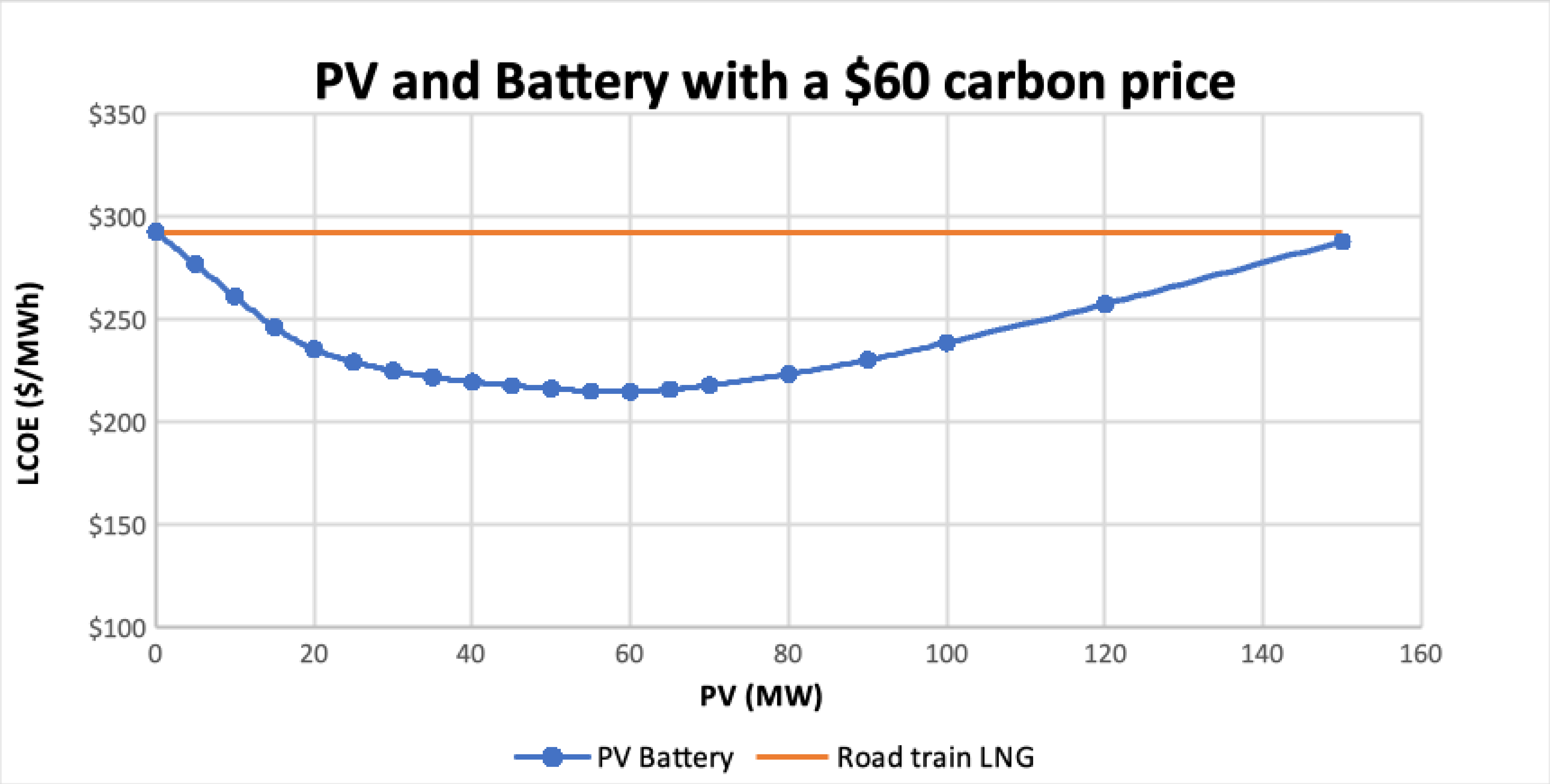
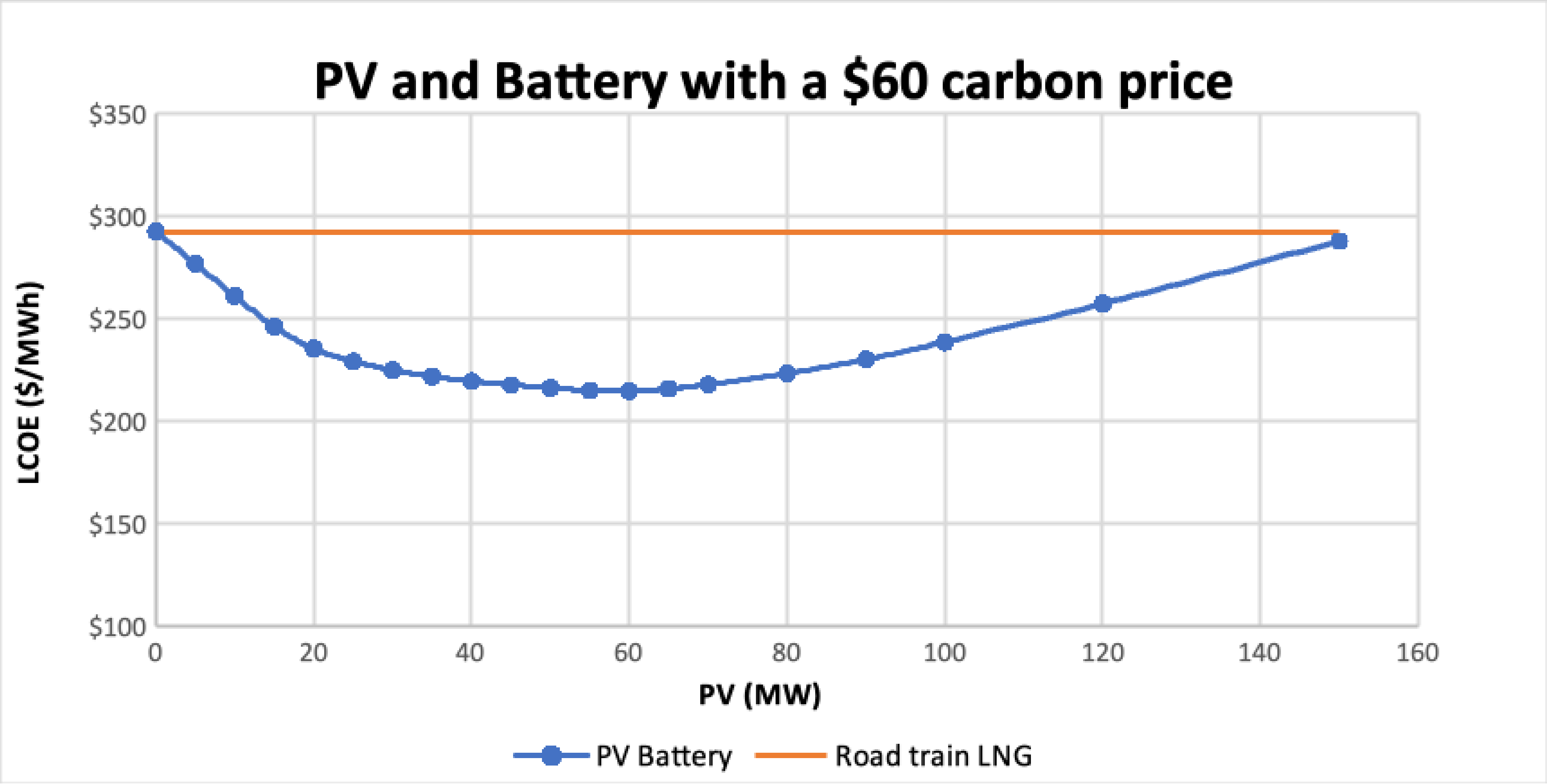
PV & Battery Results



PV & Battery Overview

Narrow cost range

But decreasing carbon emissions



Fixed PV (MW)	LCOE ($/MWh)	Battery (4h) (MWh)	RE % of Total Load
20	$235	0	32%
25	$229	10	38%
30	$225	30	45%
35	$222	50	52%
40	$220	70	58%
45	$218	100	65%
50	$216	130	72%
55	$215	150	78%
60	$215	160	82%
65	$216	162	84%
70	$218	162	86%
80	$223	164	88%
90	$230	166	90%

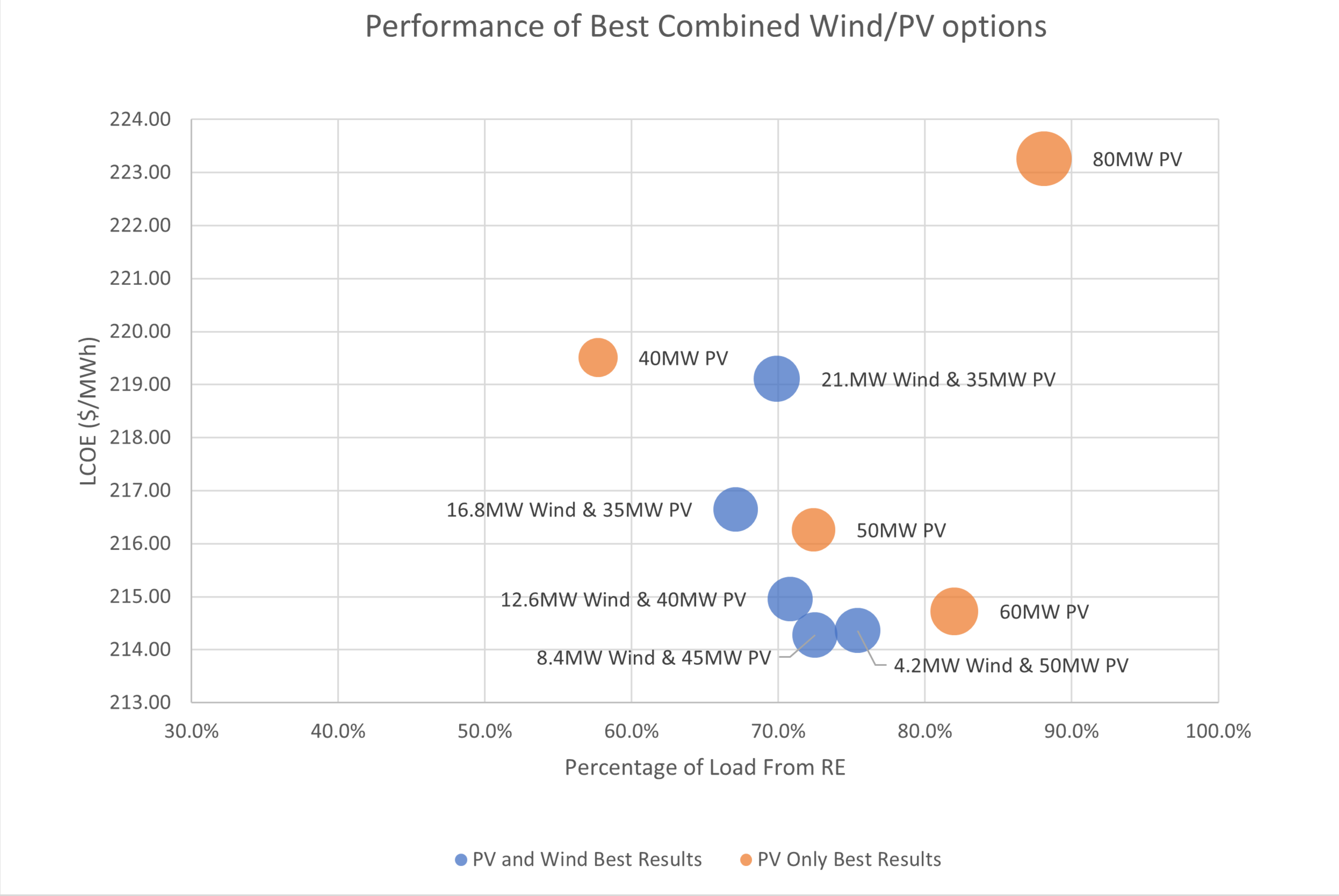
Add Wind Generation

4.2MW Vestas V117 cyclone-rated turbines

- Modelled for 1-5 turbines
- Optimised PV & Battery

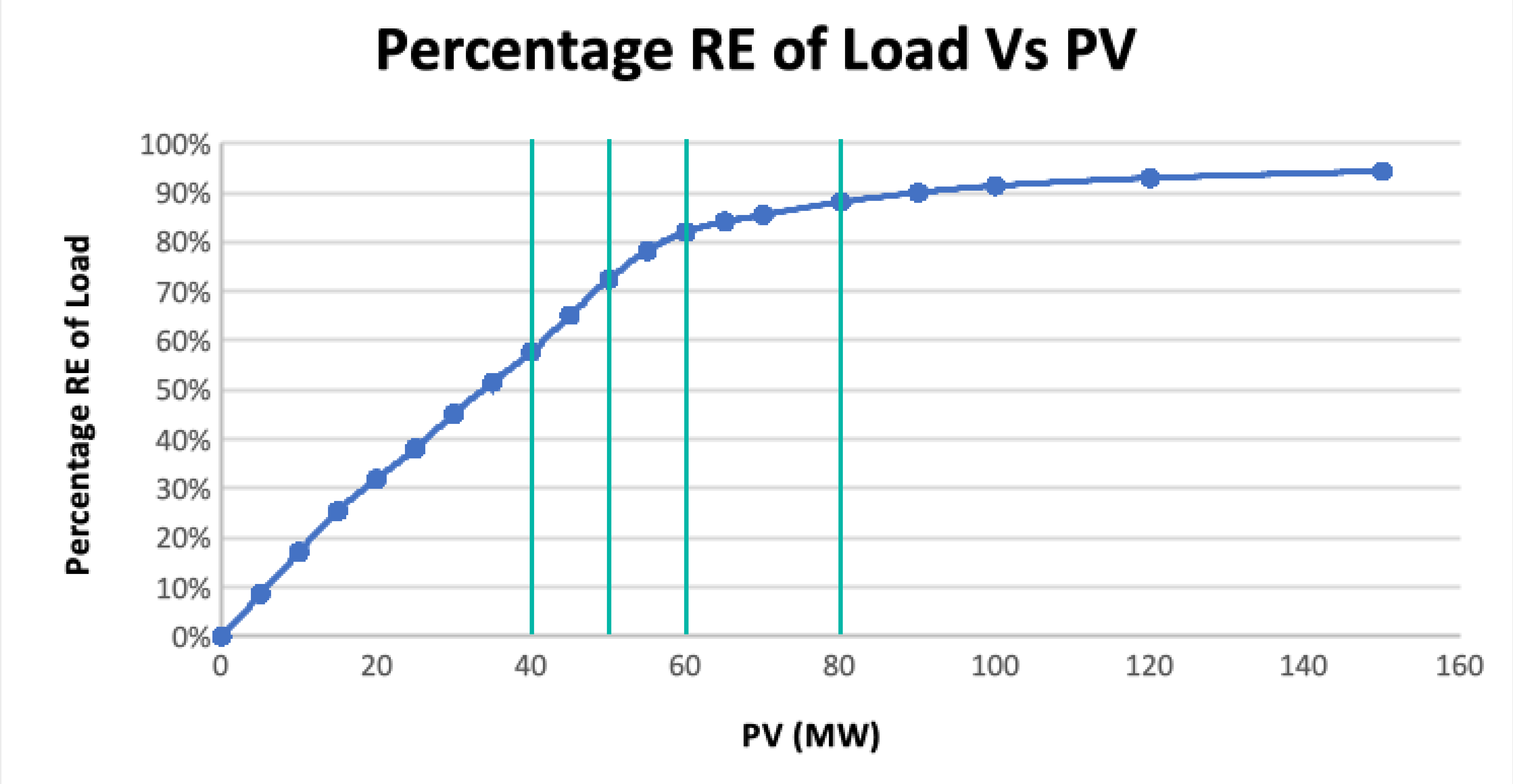
PV slightly better

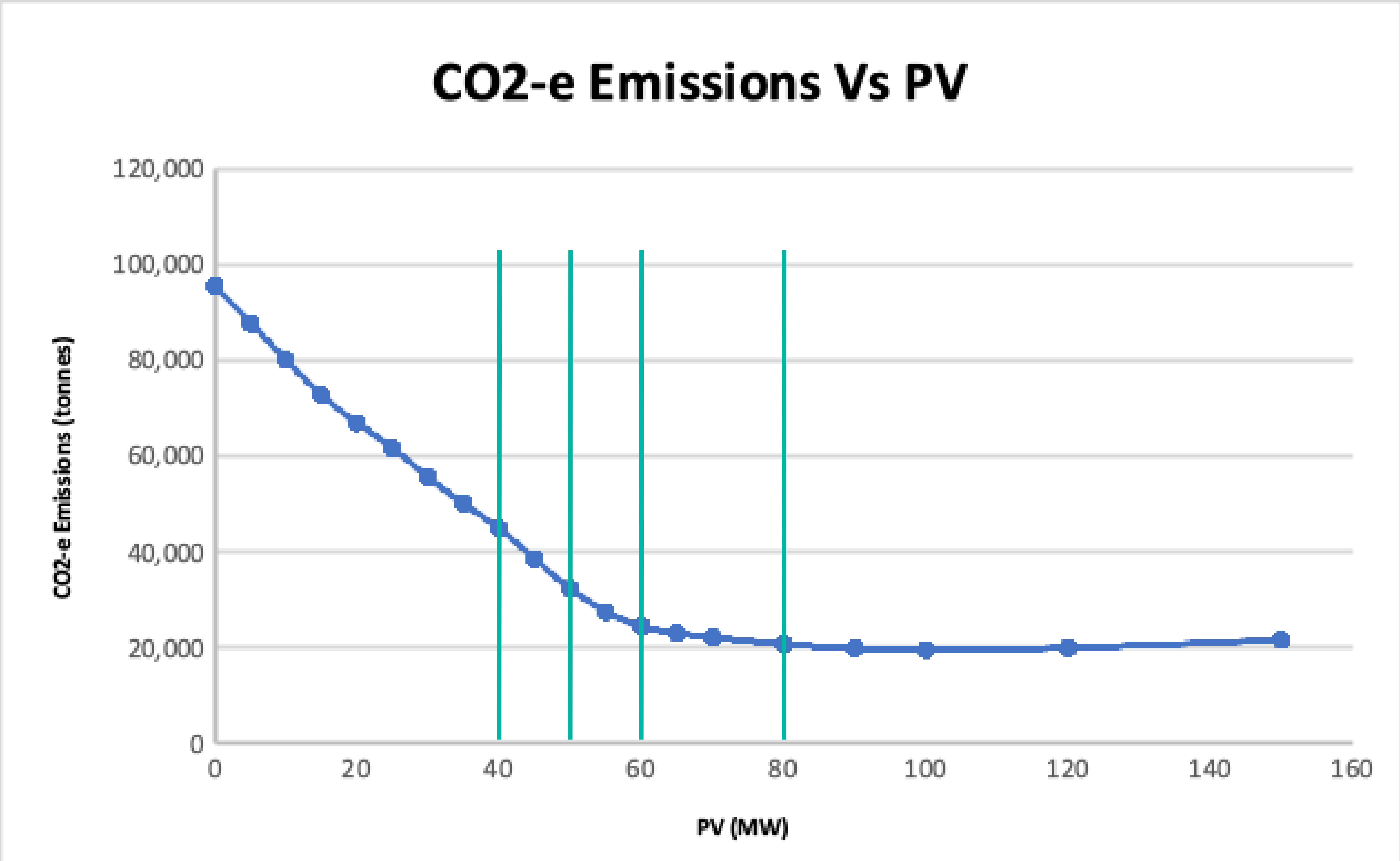
- Costs about the same
- Lower RE %
- Wind speed low in Broome
- Cyclone risk

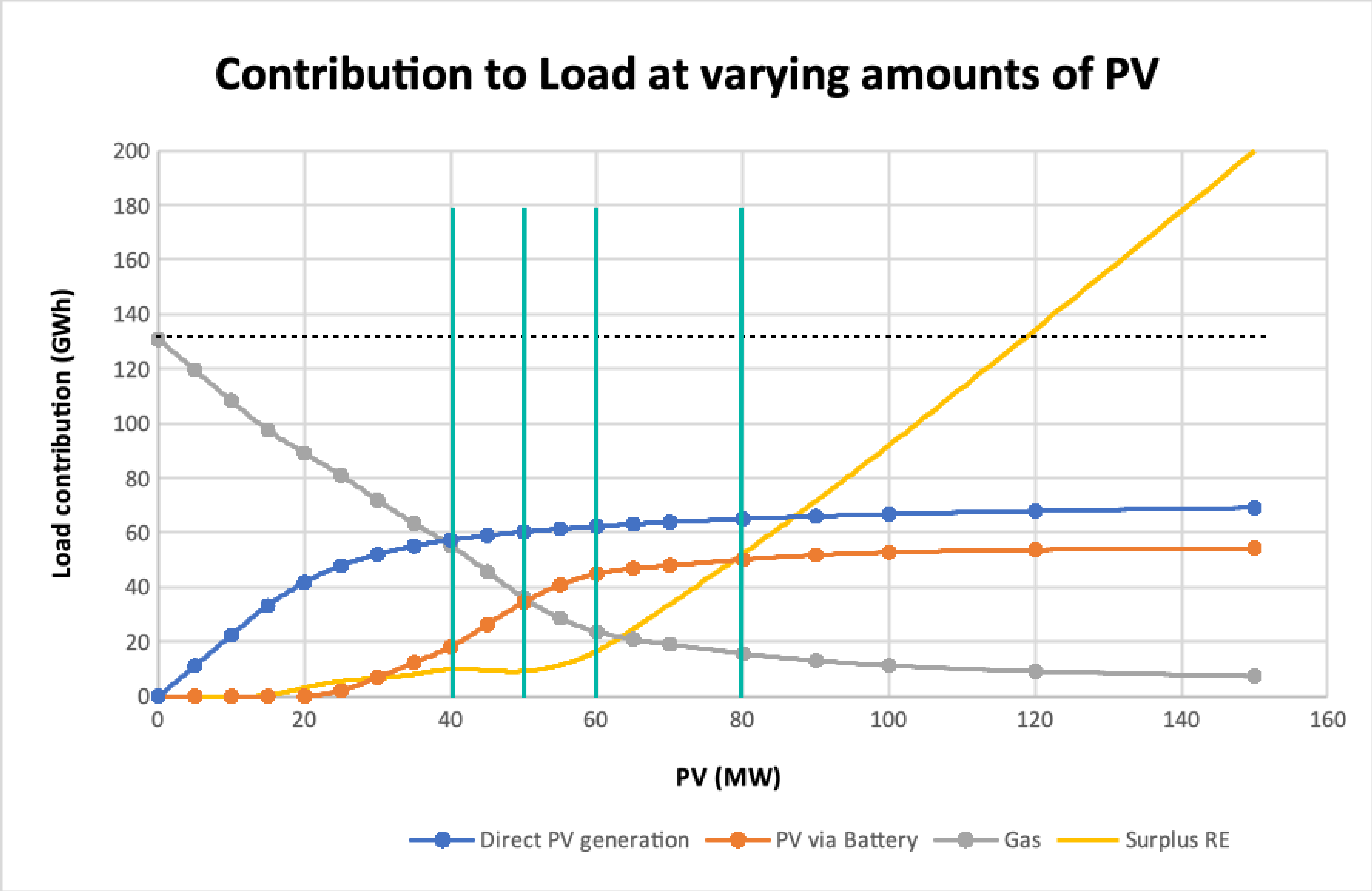


The Four Optimal Cost Solutions

PV (MW)	40	50	60	80
LCOE ($/MWh)	$220	$216	$215	$223
Battery (MWh)	70	130	160	164
LNG (MW)	30	30	30	30
RE % of Total Load	58%	72%	82%	88%
Lifetime Emissions (tCO_2-e)	44,834	32,278	24,457	20,756
Contribution to Load				
RE (GWh)	57	60	62	65
Battery (GWh)	18	34	45	50
LNG (GWh)	55	36	24	16
Surplus (GWh)	10	9	17	52


Percentage RE of Load Vs PV
Percentage RE of Load
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
20
40
60
80
100
120
140
160
PV (MW)


CO2-e Emissions Vs PV
CO2-e Emissions (tonnes)
120,000
100,000
80,000
60,000
40,000
20,000
0
0
20
40
60
80
100
120
140
160
PV (MW)



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Capital Expenditure

The four ‘optimal’ cost solutions

PV (MW)	40	50	60	80
LCOE ($/MWh)	$220	$216	$215	$223
Battery (MWh)	70	130	160	164
LNG (MW)	30	30	30	30
RE % of Total Load	58%	72%	82%	88%
CAPEX ($m)	$131m	$167m	$191m	$218m

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Rooftop vs Utility PV

Treated as one technology - similar costs

Up to 40 MW on Broome rooftops

Solar Farm: 20 - 60 MW

	Rooftop	[illegible]
Cost	Landowner pays	Gove[illegible]pays
Management	Complex [illegible]ge	[illegible]to manage
Issues	Dist[illegible]ergy Resources [illegible]ent System (DERM[illegible]	200 ha. land to be cleared. Trad. Owner consent needed. Required to replace gas in 2027.

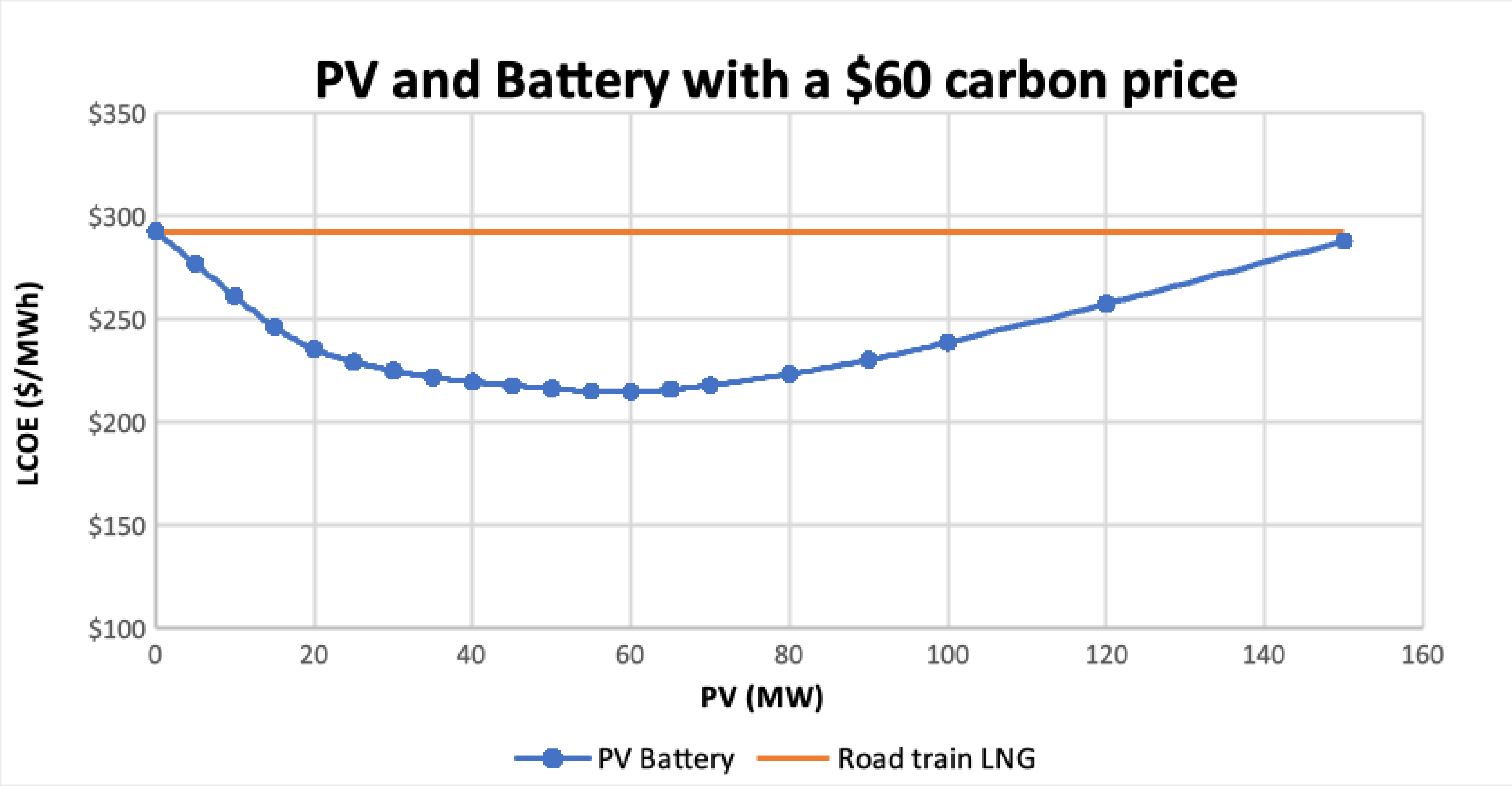
Detailed Analysis Required

Political and community decision

Implementation

Staged approach to decarbonisation

- Cost curve flat as PV increases
- How to manage the Rollout?
- Need large amount of PV by 2027
  - to replace the gas generators
- Mixture of Utility and Rooftop PV?
  - Ultimate 50 - 50 mix



Assumed Scenario for 2027

- 40 MW Utility Solar, operational by 2027
- 10 MW of Rooftop Solar, built out to 40 MW past 2027
- Battery Storage plant sized ultimately for 164 MWh (80 MW PV),
    - initially 130 MWh storage (50 MW PV)
- 30 MW of peaking gas generation - low utilisation

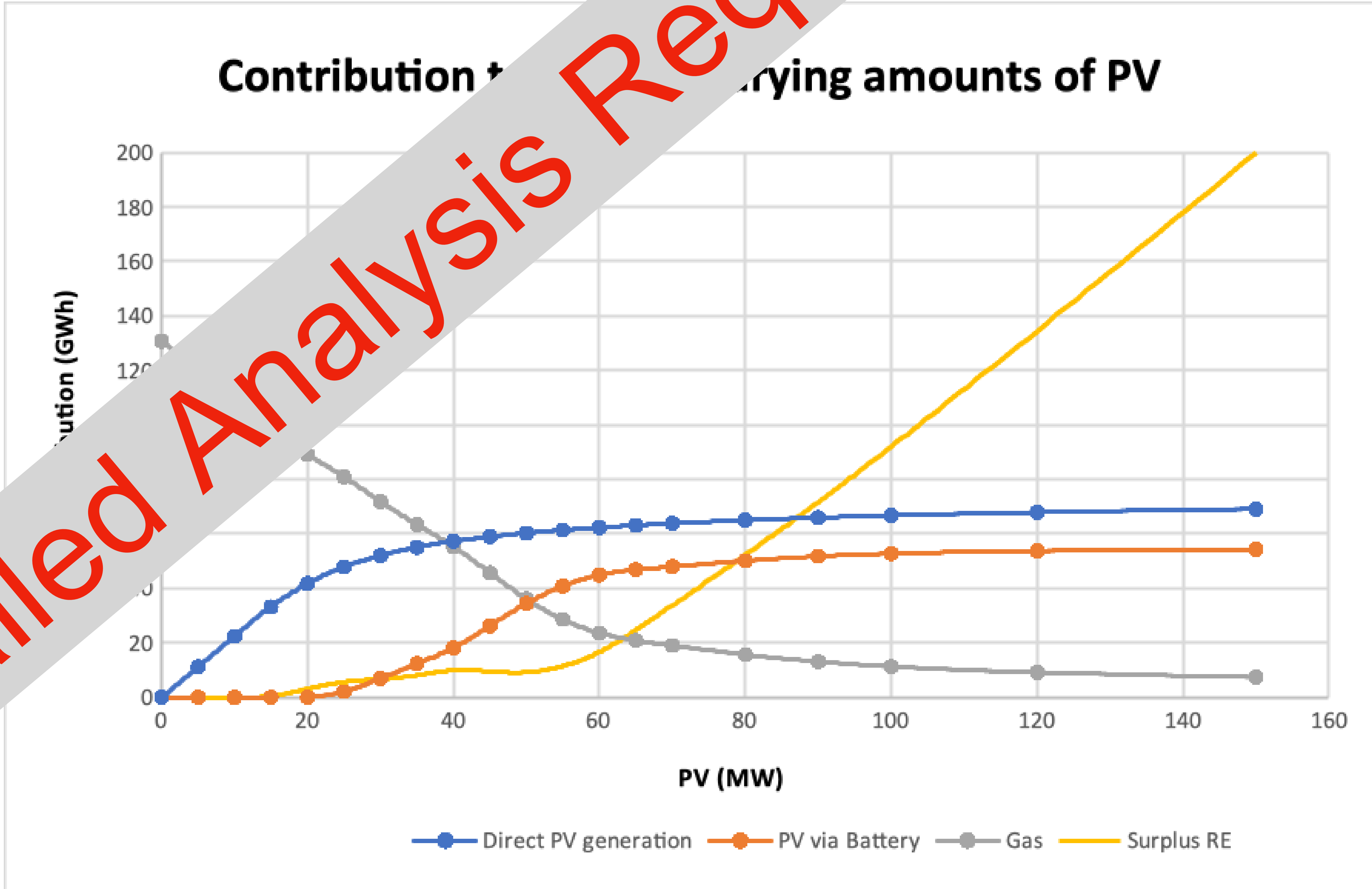
New or Refurbished Gas Generators?

In a gas-only scenario, new generators will be needed

Under the RE scenario:

- Gas generators will be used sparingly
- Don't need all at once
- So why install new ones?
- Refurbish the old ones
- We assumed refurbishment is 40% of new

Detailed Analysis Required



Capital Cost Summary

CAPEX new gas generators: $54m

Technology	Capacity (MW)	CAPEX Refurb. ($m)
Fixed PV	40	$51
Rooftop PV	10	0
Battery 4hr	130	$29
Battery Balance of Plant	164	$24
LNG – refurbished gas generation	30	$22
Total		**$126**

Lifetime Costs

Lifetime savings over 25 years: $321m

Technology	Lifetime cost – New gas. ($m)	Lifetime cost – Refurb. gas ($m)
Fixed PV	$144	$144
Rooftop PV	$36	$36
Battery 4hr	$158	$158
LNG - new and refurbished	$369	$298
Proposed scenario Total	**$707**	**$636**
100% gas	**$957**	

$321m

Expenditure Summary

Technology	82% RE	New LNG	Difference
Capital expenditure (up front)	$126m	$54m	-$72m
Lifetime costs (25 years)	$636m	$957m	$321m

An extra up-front expenditure of $72m is offset by a saving in total lifetime costs of $321m.

This is a great story!

Electricity generation in Broome can be achieved with

- over 80% renewable energy
- at three quarters of the cost of gas-fired (LNG) generation

Total lifetime savings of $321m

But wait. There’s more!

Outline

Transition to 100% Renewables

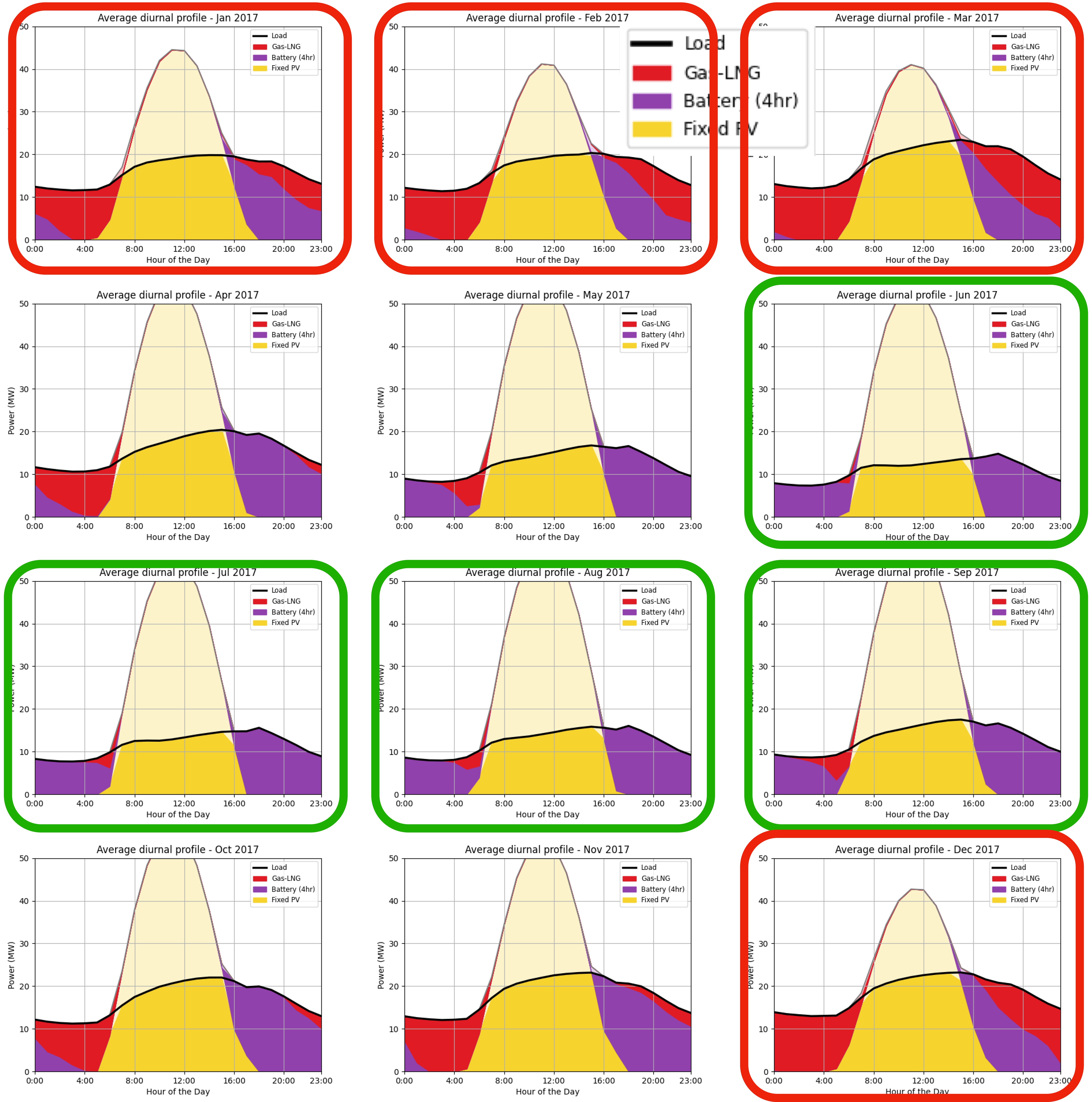
What are some of the issues?

- Weather factors
- Fuel factors

Seasonal Factors

Wet vs Dry

- Jun-Aug - almost 100% RE
- Dec-Mar - *some* LNG needed



July vs March

Long Duration Energy Storage

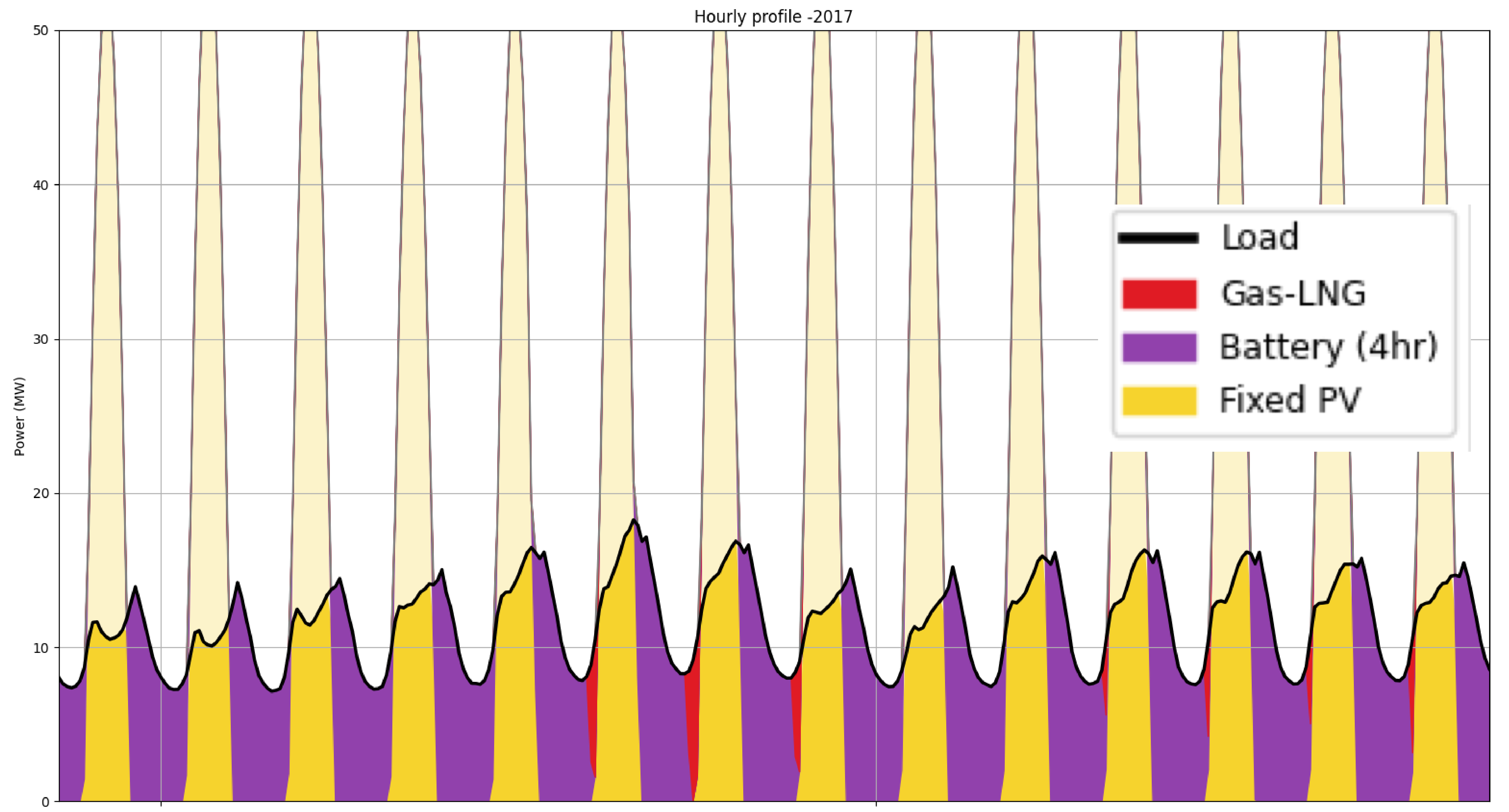
LNG & Diesel

- but emissions continue

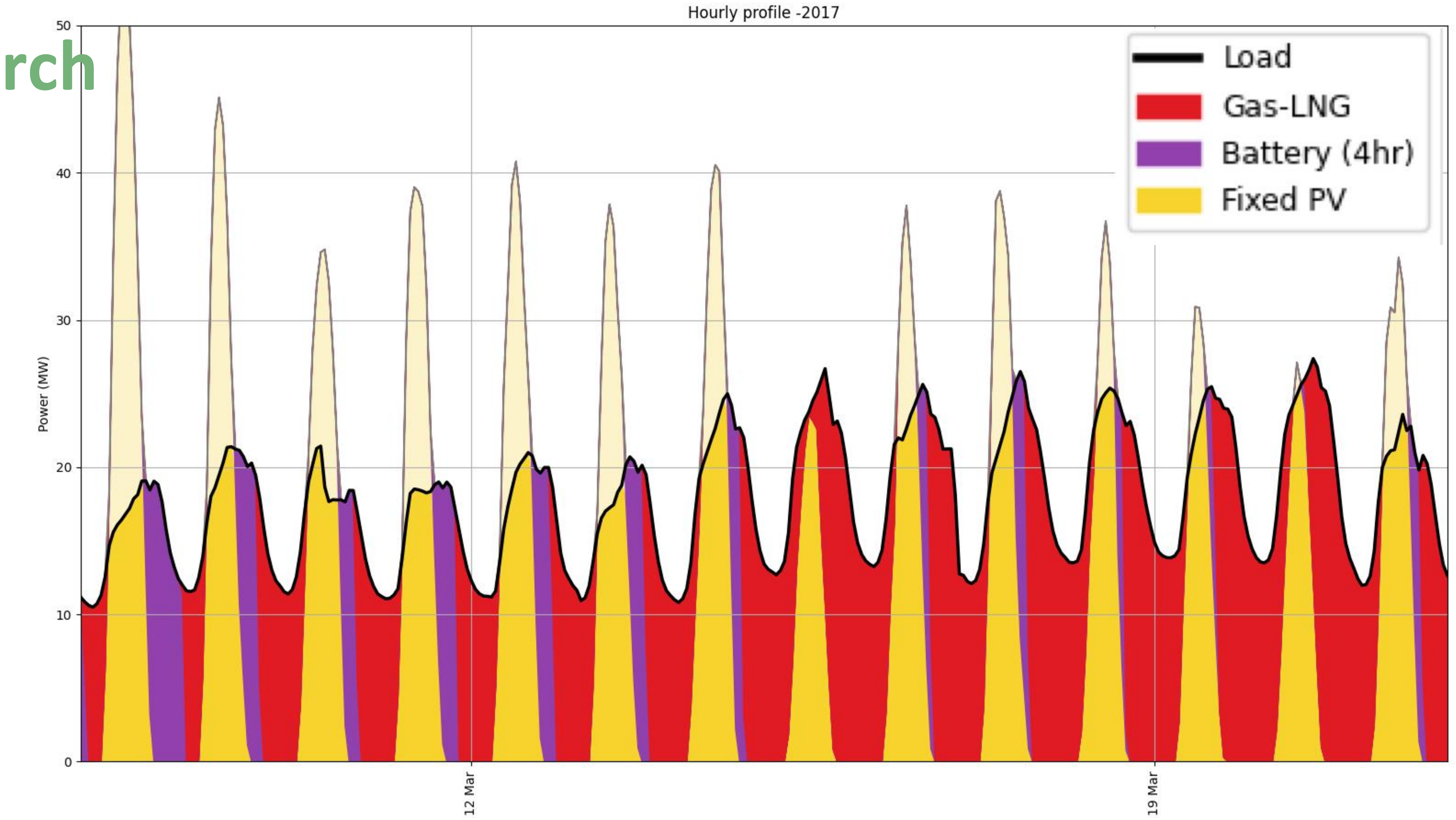
Potential alternatives?

- Pumped hydroelectricity
- In-stream tidal turbines

July



March



Tidal Turbines

- Immature technology
- Scotland

July vs March

Long Duration Energy Storage

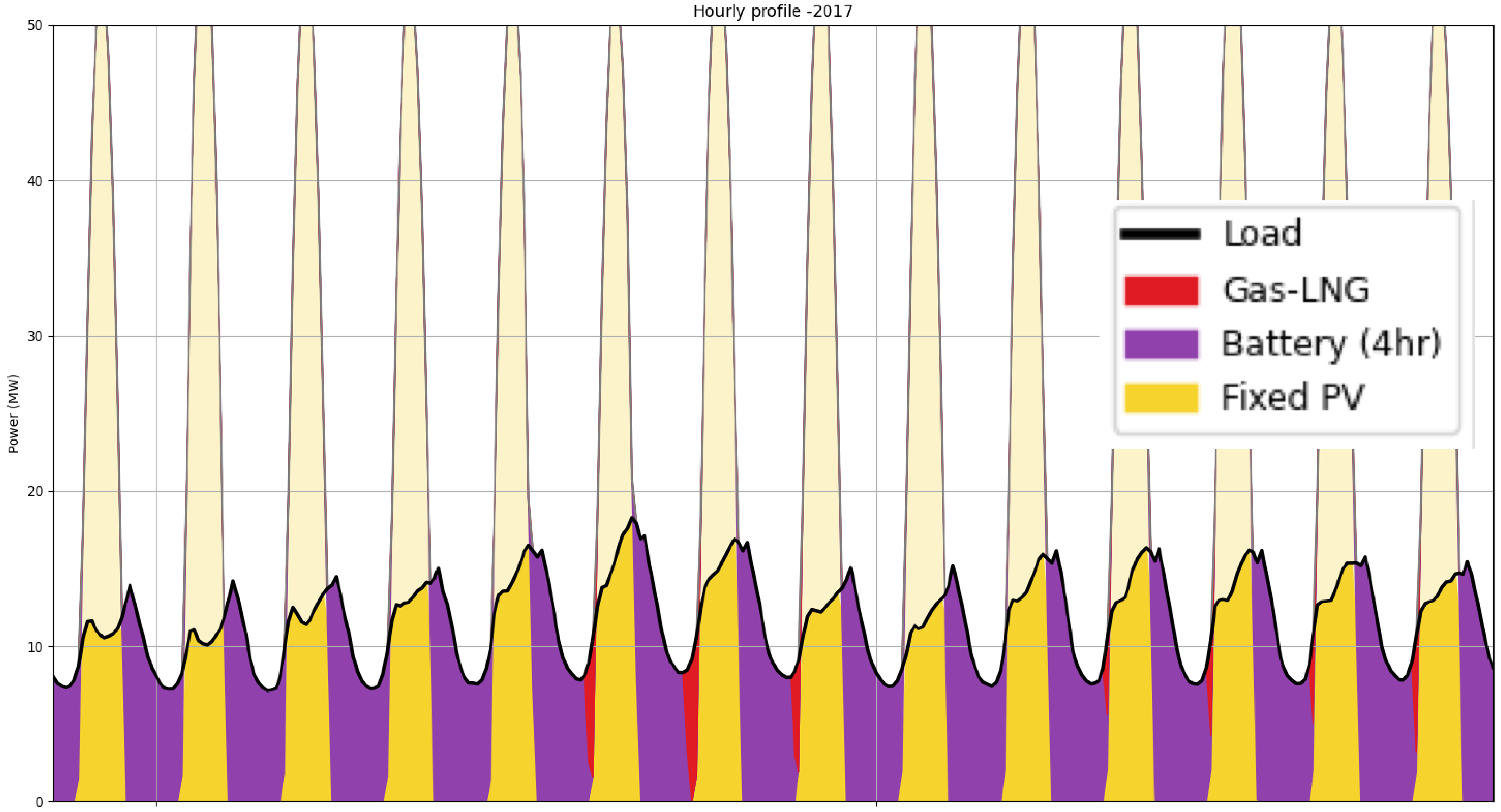
LNG & Diesel

- but emissions continue

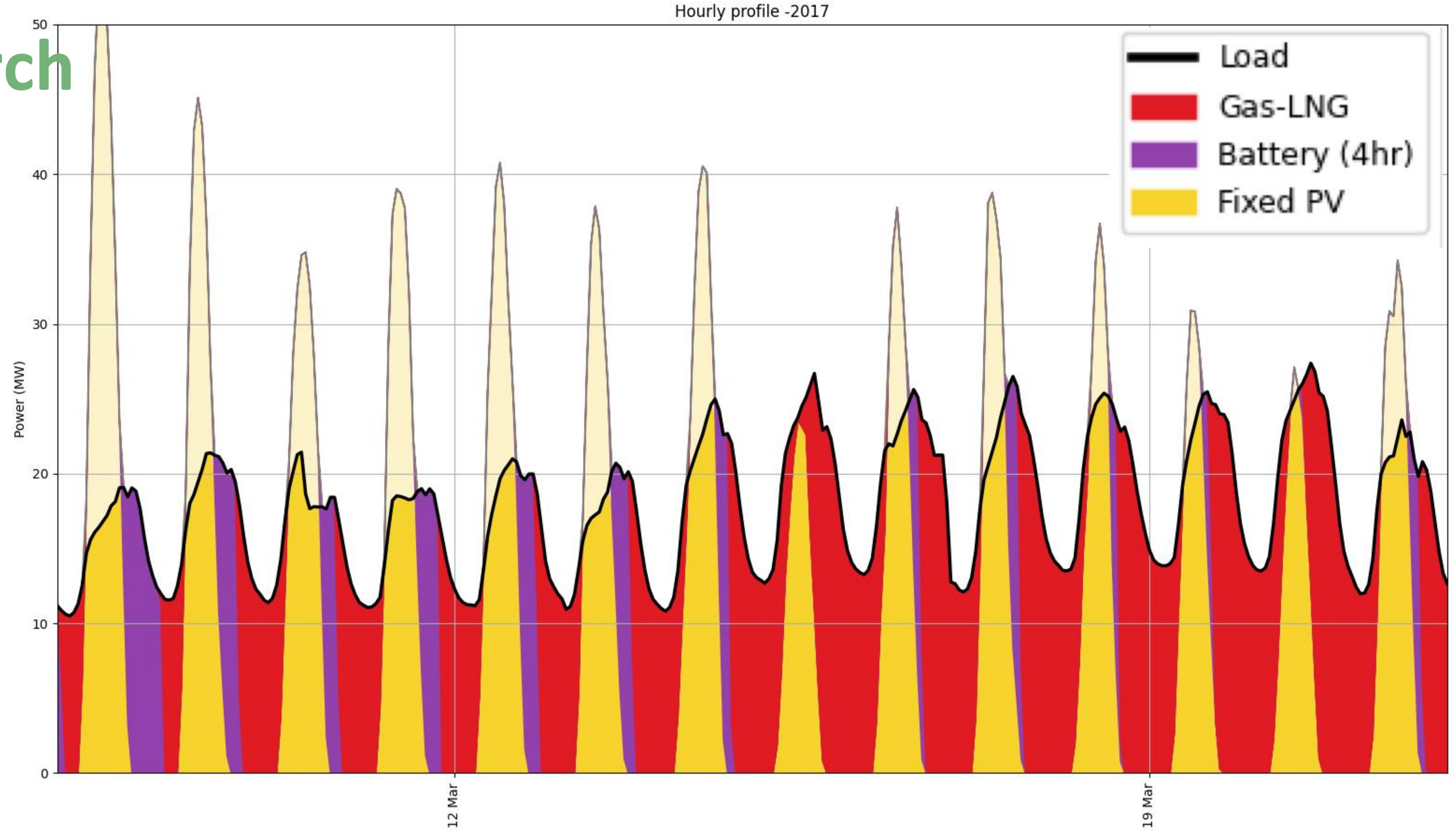
Potential alternatives?

- Pumped hydroelectricity
- In-stream tidal turbines
- Hydrogen/ Ammonia

July



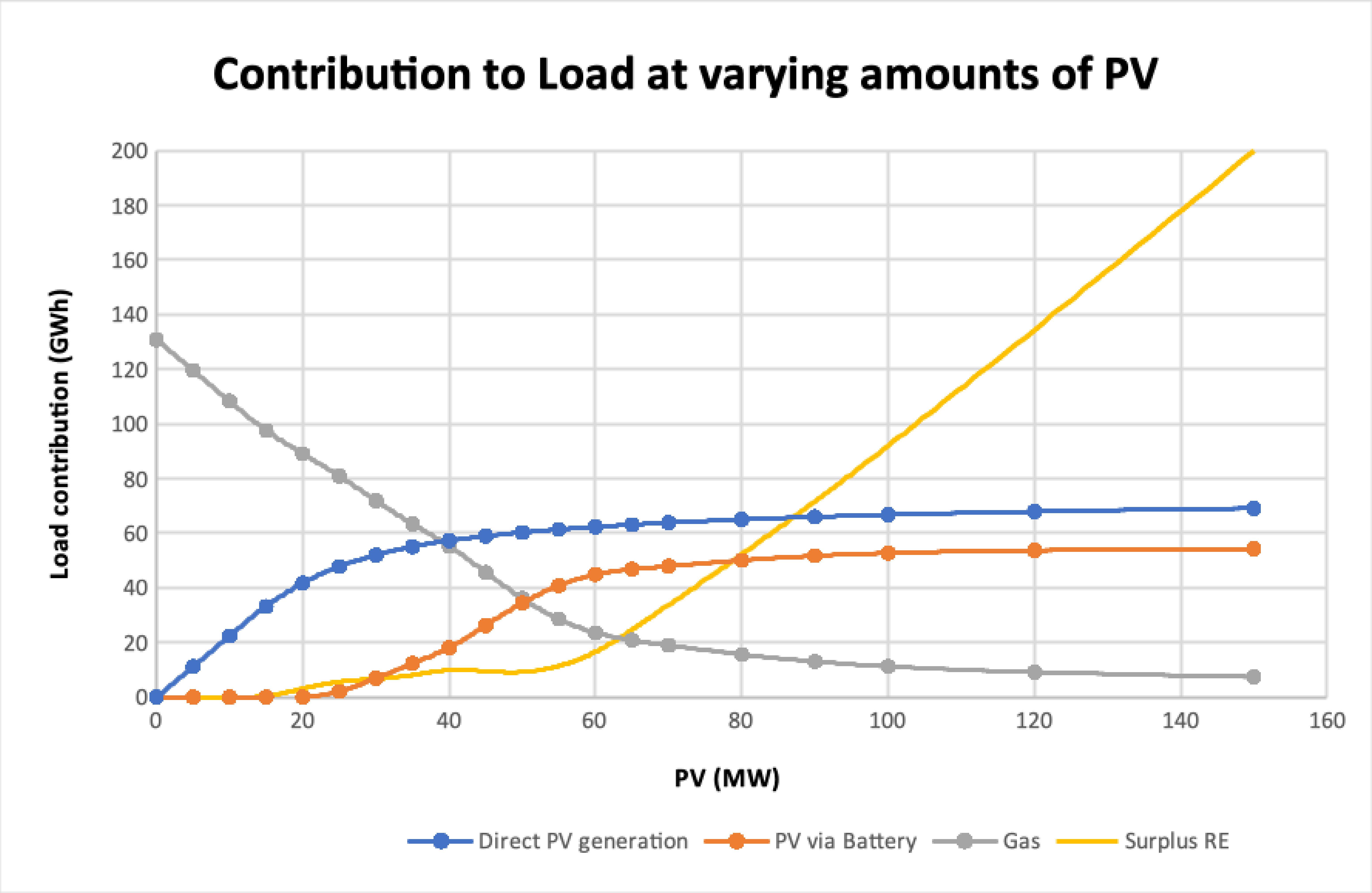
March



Surplus Renewables

What to do with it?

- Use the surplus to produce hydrogen as a fuel
- Other opportunities?



Surplus Renewables

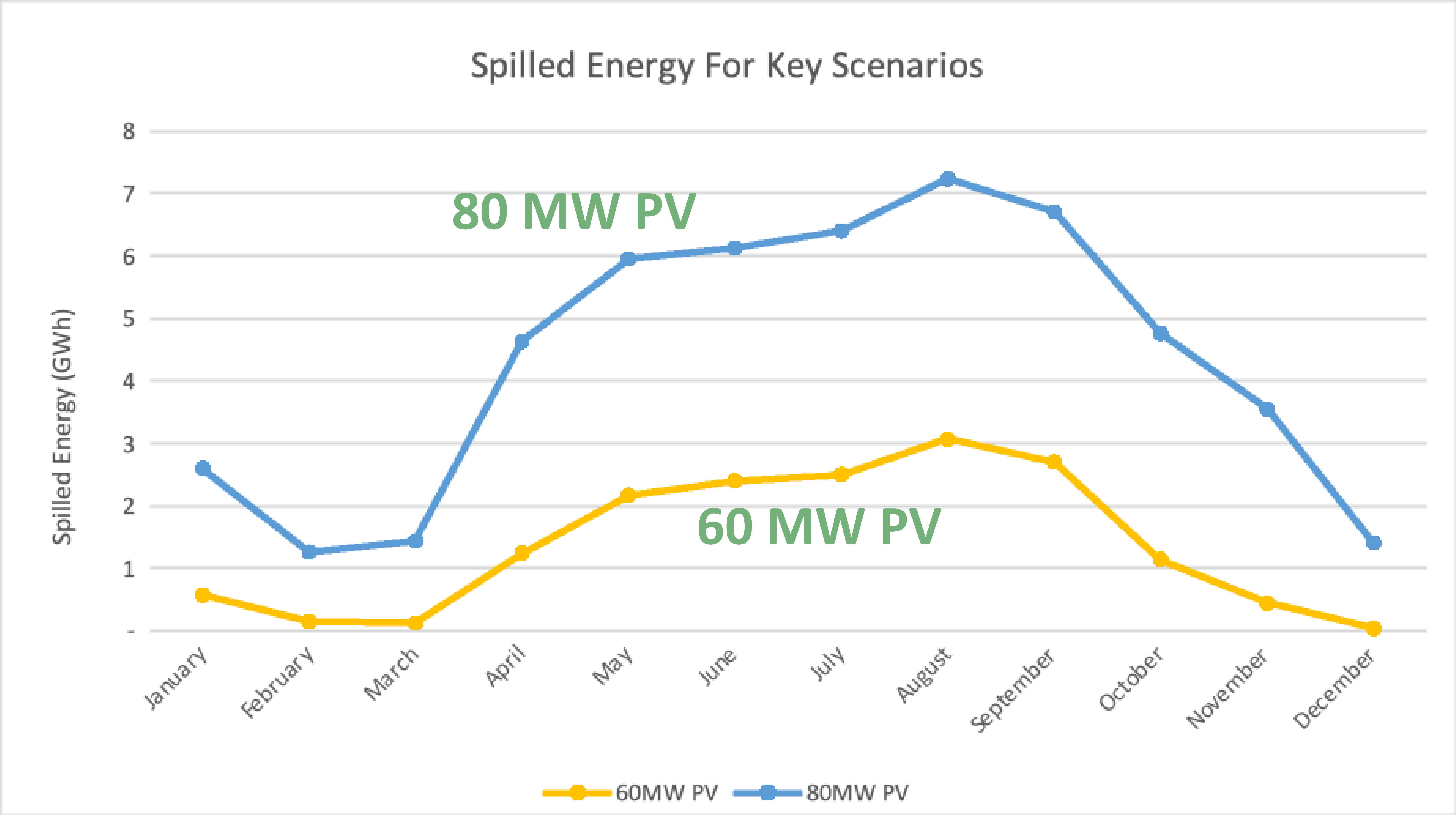
Seasonal factors for Hydrogen

Little surplus when needed

- Wet

Lots when it's not

- Dry



Hydrogen Issues

Not an immediate solution

- Generation - electrolysis - solvable
- Storage - difficult - need 6 months' supply
- Transport - very difficult - pipe leakage
- Maybe ammonia by road train

Phenomenal rate of investment and advancement in H_2

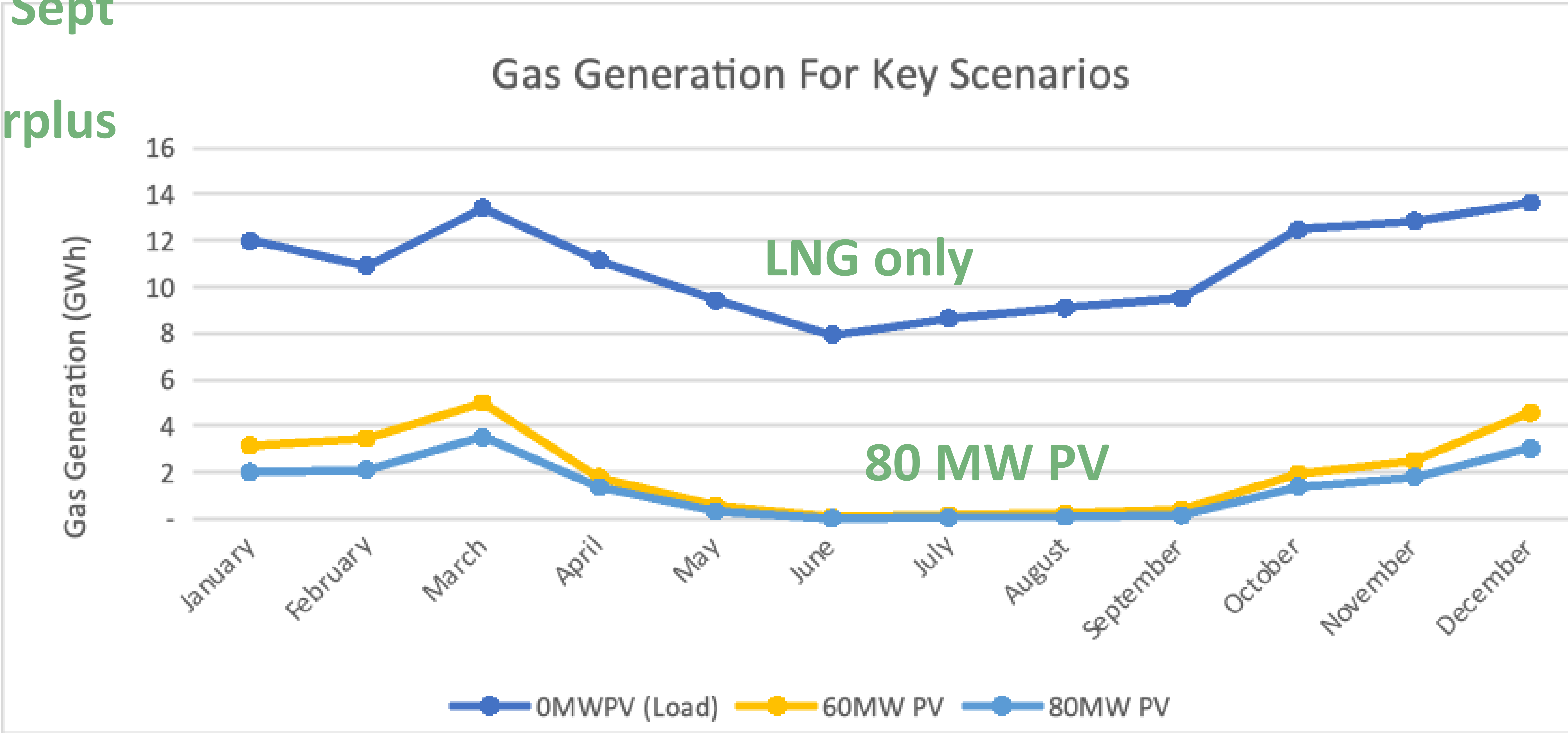
Seasonal Gas Use

Opposite to hydrogen

Most gas use Oct - Apr

Negligible gas use May - Sept

- **When there is a PV surplus**



LNG Issues

In a high RE scenario

Currently 1 road train per day

- Will reduce to 1 per week

Stored in an insulated tank

- Gas ‘bleeds off’ as it warms - what if it’s not needed?
- Losses and leakages - flaring?

Financial challenges for gas supplier

- Shipping LNG from Karratha will become uneconomic
- Stranded assets

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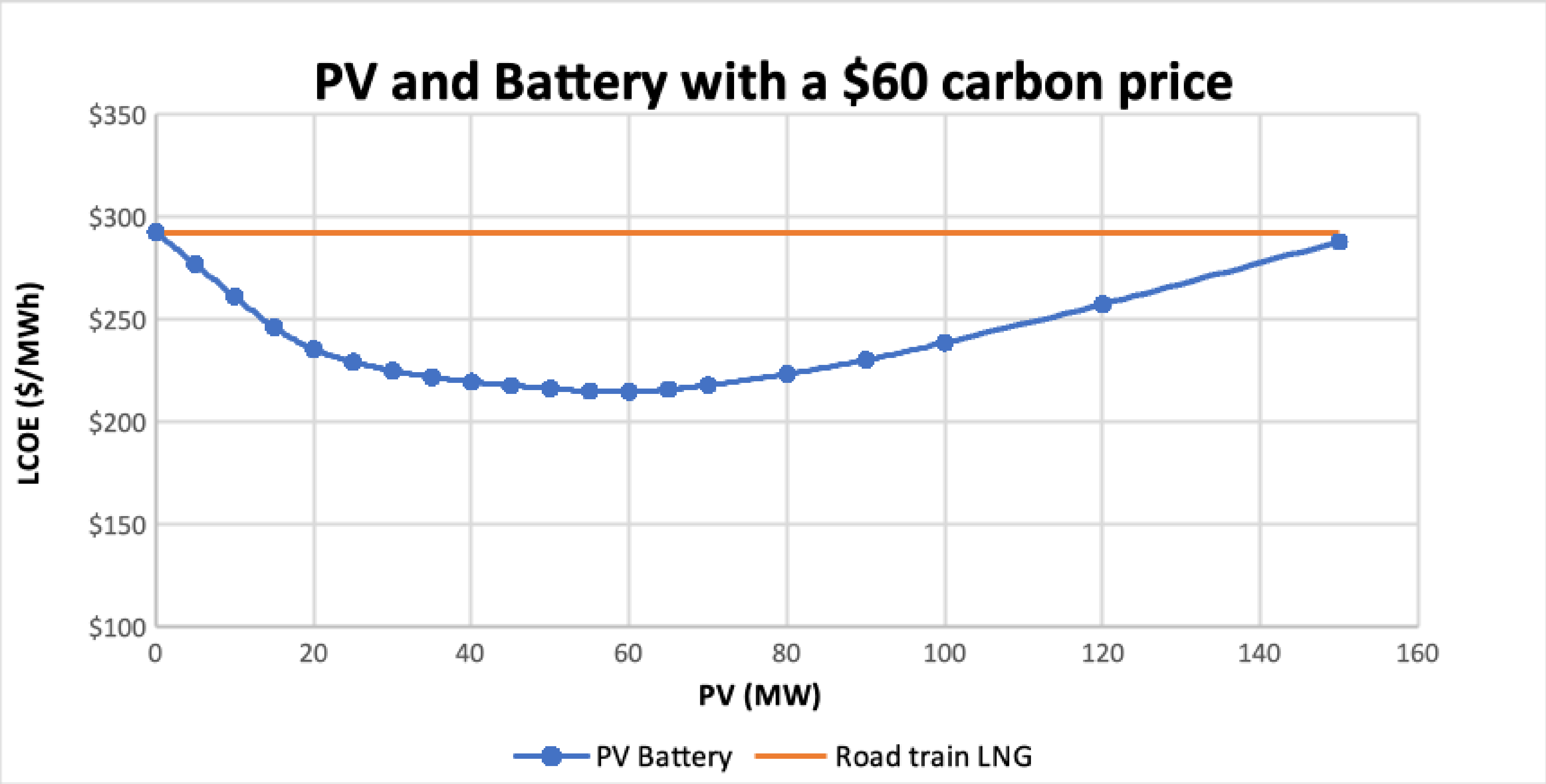

100% RE currently not financially feasible

- seasonal factors

PV (MW)	40	50	60	80
LCOE ($/MWh)	$220	$216	$215	$223
Battery (MWh)	70	130	160	164
LNG (MW)	30	30	30	30
RE % of Total Load	58%	72%	82%	88%
CAPEX ($m)	$131m	$167m	$191m	$218m

Horizon Power

More work needed

One of the most progressive power utilities in Australia

- Future Energy Systems Group

Relatively small steps towards ‘proof of concept’

- Hamstrung by government rules - minimum cost
- Project Eagle - Energy and Governance Legislation Reforms
  - New project rules (2023) to include reduced emissions as well as lowest cost

HP can now go further!

Actions

Horizon Power

- **Determine the optimal mix of rooftop and utility PV**
- **Commission a 20+ MW solar farm by 2027**

Broome community:

- **Engage proactively with Horizon Power**
- **Continue to advocate for higher levels of rooftop PV and supporting battery storage**

Conclusion

Roll this out!

High levels of RE across regional and remote WA

Powermatch is a powerful tool

Applying it to the SWIS

- Solid data around replacing coal generation

Advocacy

- Pointing out that the State Government needs to do much more
- and quickly!


The future is not so gloomy!
Questions?

LCOE vs % Renewable Energy

- Explain the hockey stick