Adaptive Planning – Navigating Future Uncertainty with Increased Confidence

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The Future is uncertain and Organizations around the world face unprecedented risks and challenges in relation to climate adaptation - in many cases this is against a backdrop of under-investment…

<u>Further, the investments choices we can make to solve and mitigate these challenges are also uncertain.</u>

Key Themes to Cover

- The importance of shifting to a proactive climate event planning approach.
- This shift means consideration of multiple uncertainty dynamics.
- How we can frame Uncertainty Quantification in an Asset Investment Planning (AIP) context.
- Having carried out advanced AIP and generated multiple pathway futures, how can we be confident in a plan, whilst also ensuring it can adapt?

Asset Intensive Organizations Face a Series of Dynamic, Long-Term Challenges

Adaptive Planning Examples

- **Long Term Water Resources Management**
- **Energy Transition**
- **Ports**
- **Process GHG Emissions – Net Zero Planning**
- **Drinking Water Quality Programs**
- **Data Network Infrastructure**
- **…**

Challenges Faced

- **Climate Forecast Uncertainty**
- **Consequence of a changing climate** over the long-term, as well as increasing probability of major events
- **Growth,** as well as **changing customer demands**
- **Mitigation Identification Uncertainty**, and;
- **Mitigation Delivery Uncertainty**
- **Long Term Strategy formation** and adoption, as a result of compounding uncertainties…

Resolving these can deliver real benefits…

Planning capability for many potential futures

- Ensuring Asset Management Plans can adapt to adversity.

Justification of long-term investment cases:

- ‘No Regrets’ decisions required in both benign and adverse futures
- Identification of activities to enable future options remain open

Build trust and confidence in long-term planning

- E.g. UK Public listed firms are adopting methodologies and securing Government endorsements for enhanced investment

Large Water Utility Example

- Increasingly, we are observing climate events that result in a number of hazards impacting security of supply of critical resources – if we look at a rich example of a water mass balance challenge…

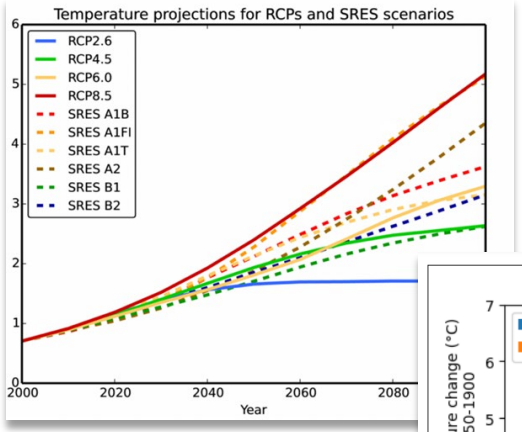
- **Climate**, **Growth**, **Demand**, **Environmental** and **Policy** drivers mean that many Water Utilities face likely, significant long-term deficits – in the order of 100's of Ml/d in the next 20+ years.

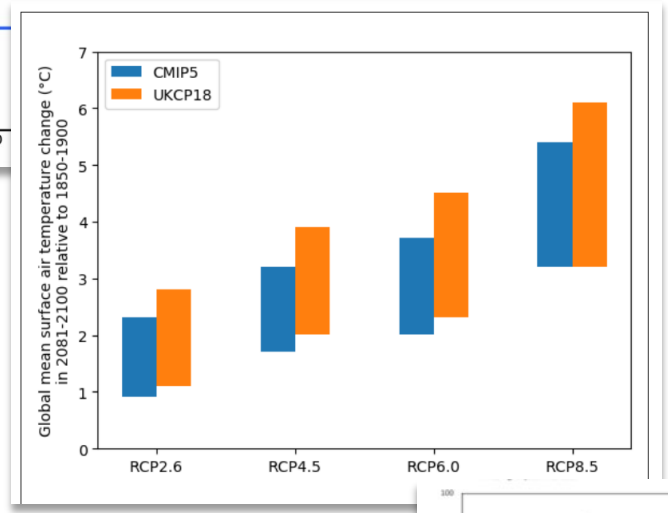
- In some geographies, this has led to Regulation shifts (e.g. least cost -> best value) and consideration of planning for resilience up to **1 in 500 year** events – relatively unheard of in recent planning periods

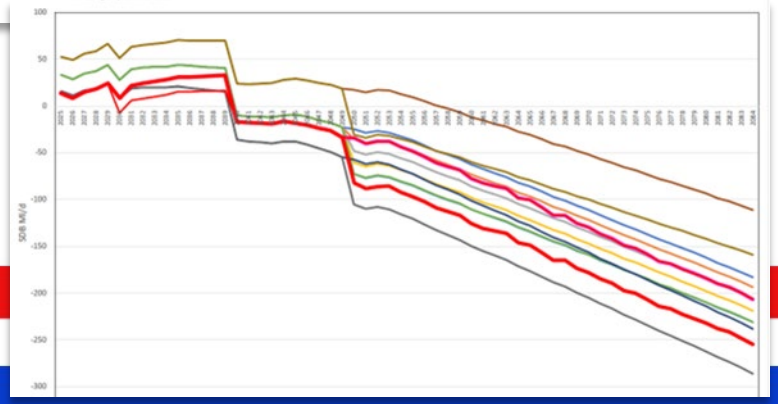
- Whilst we cannot accurately predict when these major climate events will occur, we can (and do):

    - Consider and model uncertainty range forecast impacts on measures, such as SDB;
    - Assess the resulting planning decision impacts
    - Formulate optimal mitigation strategies earlier

External Investment Drivers







- Whilst the future is uncertain, we can utilize the various modelled ranges to great effect;
- The broad range of impact does not preclude us from carrying out robust investment model uncertainty quantification.
- However…

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https://www.ukclimaterisk.org/wp-content/uploads/2021/06/CCRA3-Chapter-1-FINAL.pdf
https://www.severntrent.com/content/dam/dwrmp24-st/STdWRMP24-Appendix-F-Decision-Making.pdf

‘Intrinsic’ Investment Uncertainty

The asset investment options to achieve respective measure targets, address known risks etc. are themselves uncertain. The key areas of uncertainty are around:

- **Cost** – by their nature, major projects/programs are impacted by numerous factors that affect outturn costs
- **Benefit** – benefit valuation methodologies carry varying uncertainties, which are essential to consider
- **Lead Time to Benefit Delivery** – often an overlooked parameter in asset investment planning – some problems/scenarios are sensitive to timely delivery

That's all very interesting, but so what?

To recap – UQ is important, however given the resultant complexity – how can we move forward from a planning perspective? We have worked with many organizations to frame solutions to this problem, in order to provide confidence in planning decision making – broadly speaking this looks like:

Step 1

- **Uncertainty Quantification –** Model Input and Output Uncertainty Analyses
- Quantify the planning **'Solution Space'**

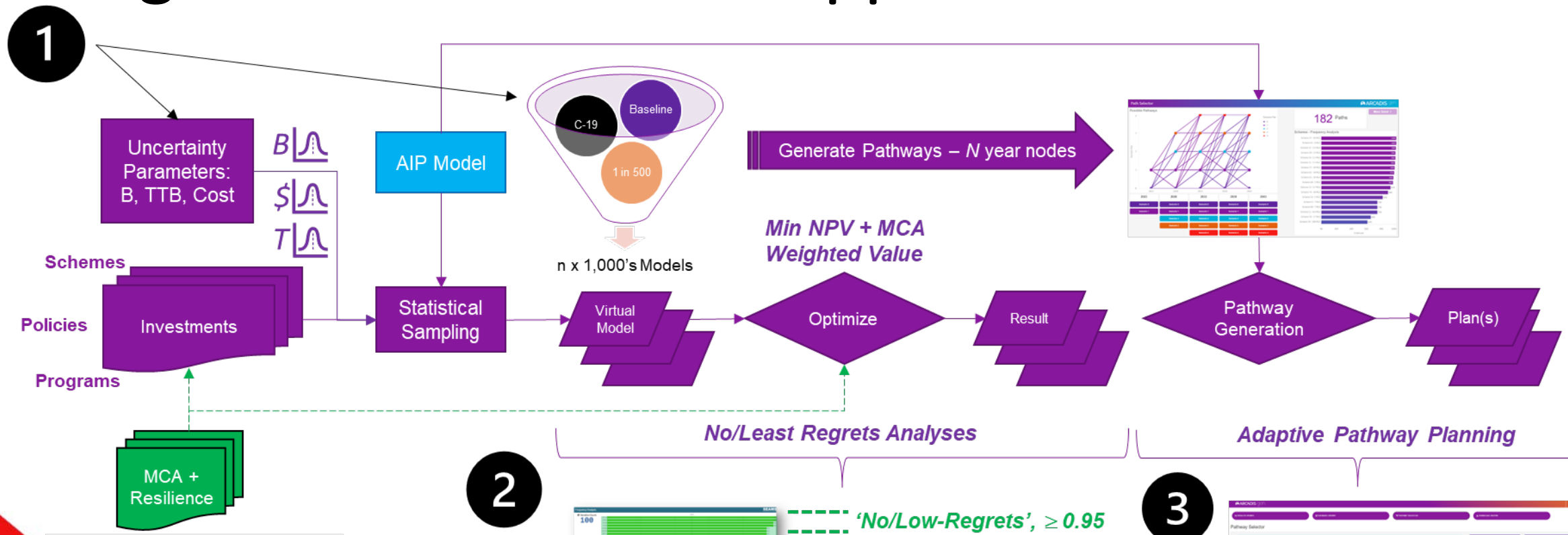
Step 2

- Run many advanced investment optimization scenario analyses - **no/least regrets analyses**
- **Identification of choices that are resilient to multiple futures**

Step 3

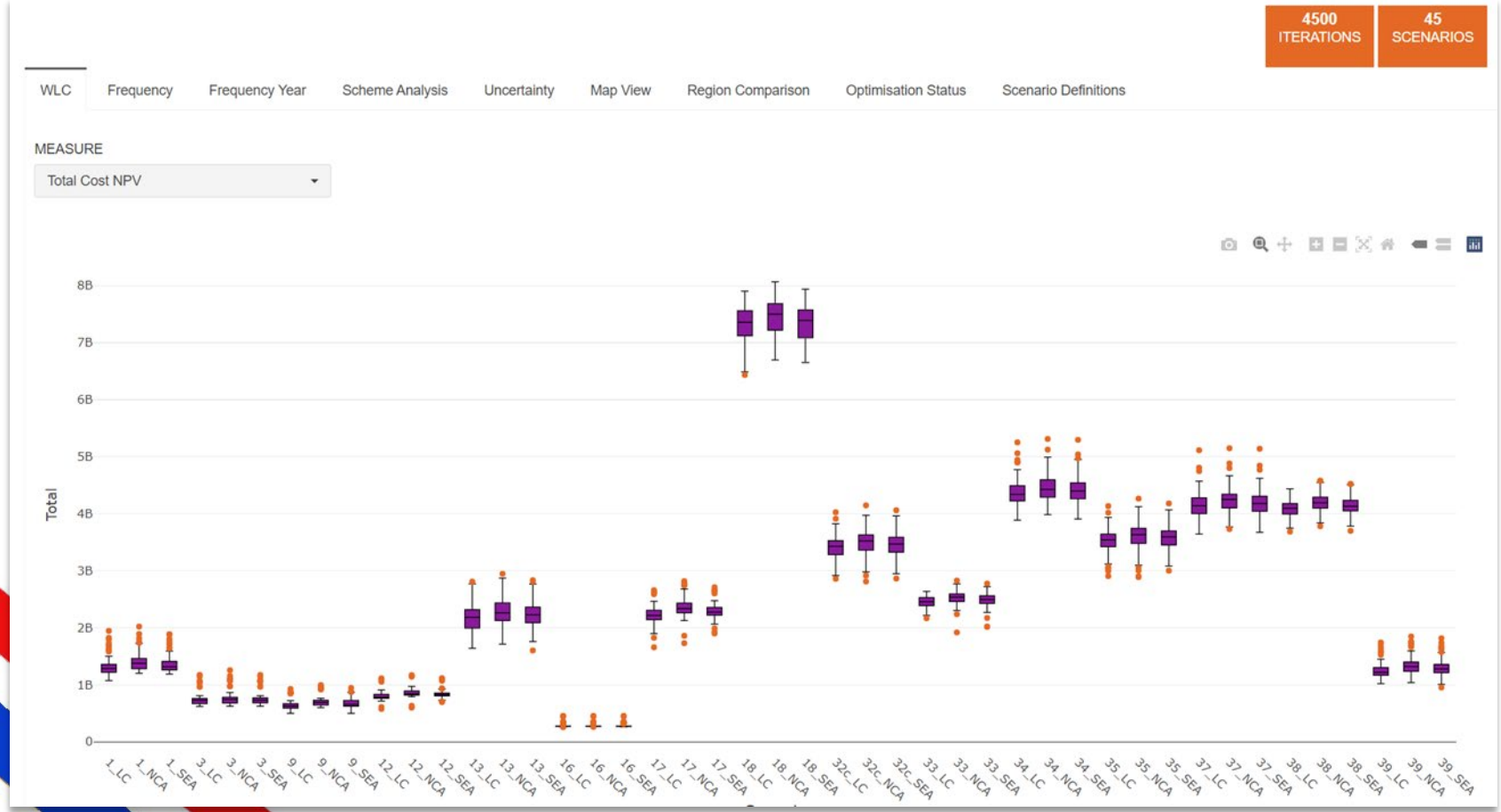
- Steps 1 and 2 are important steps, however are relatively immature methodologies in many sectors
- Assuming 1+2 have been carried out, there is still the 'so what' step i.e. ***how do we translate multiple futures analyses to an investment plan that can also adapt, as the actual future becomes apparent?***

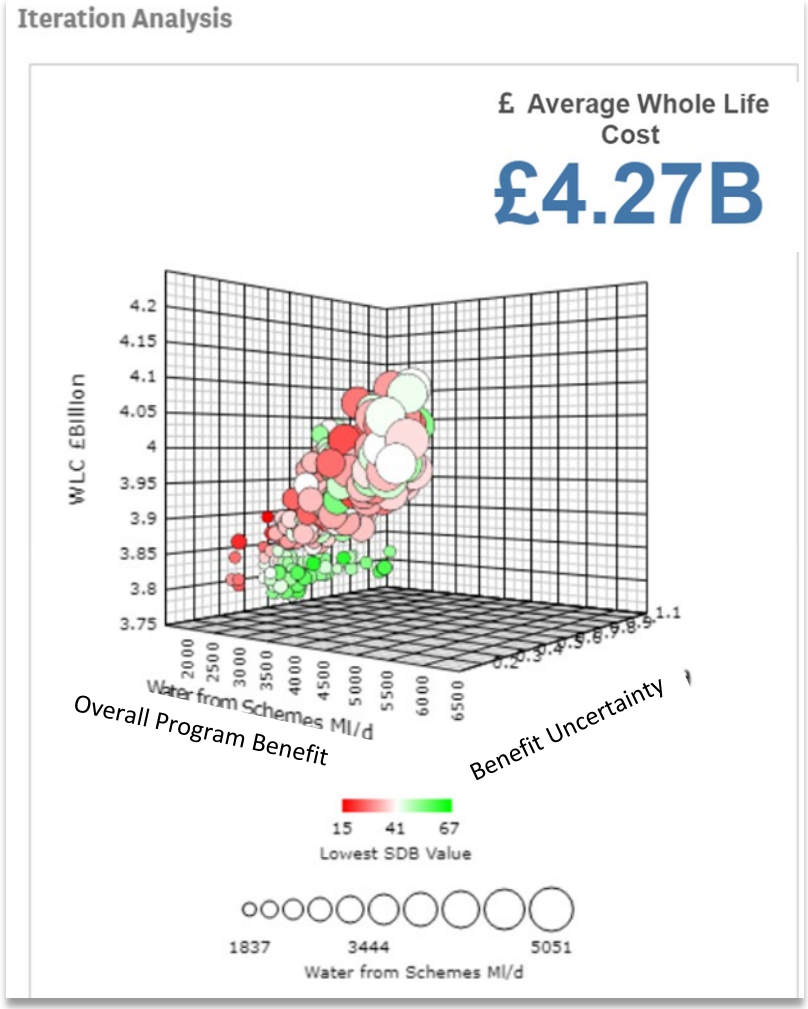
High Level View of the Approach



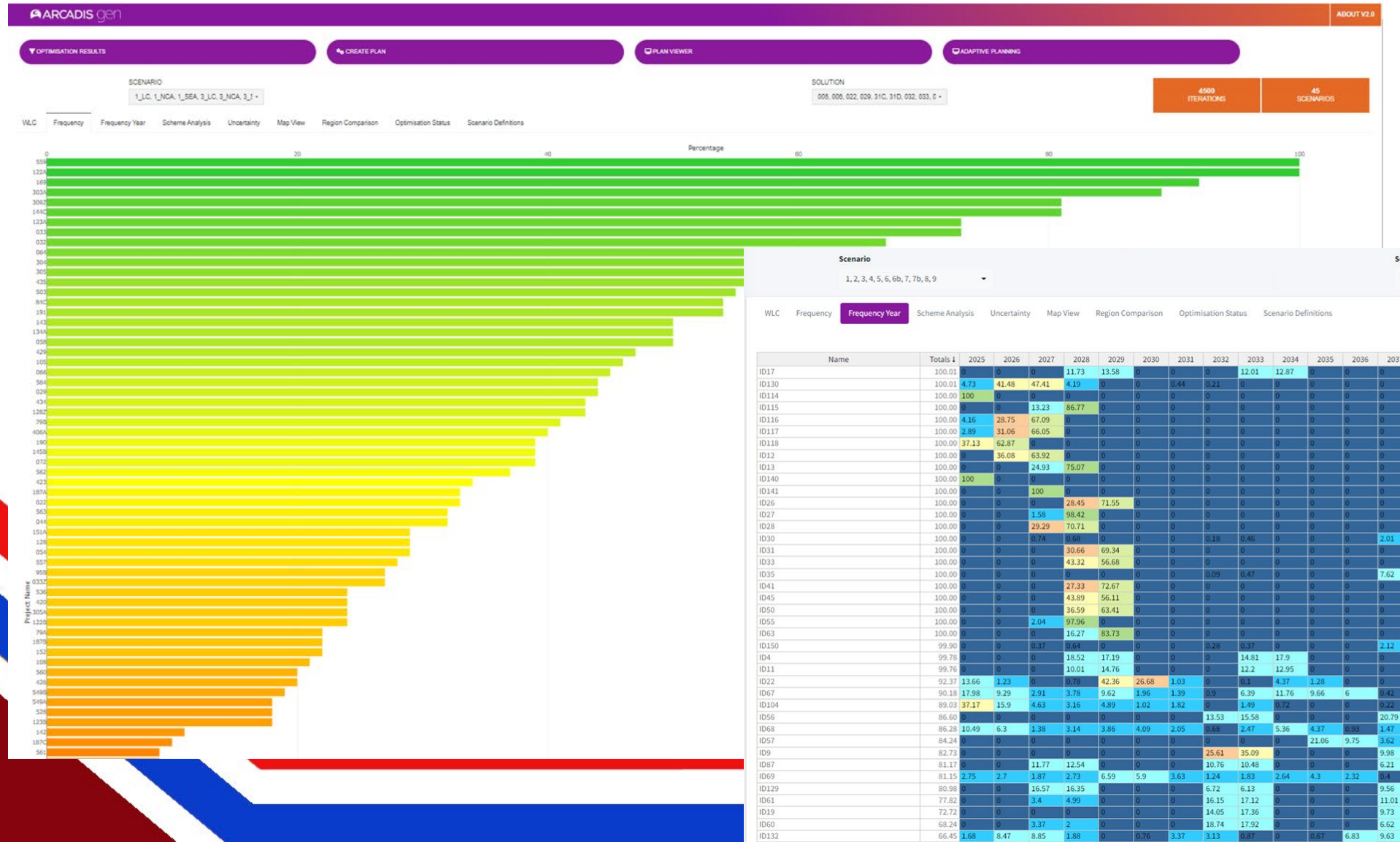
- *Human/Social Wellbeing*
- *Biodiversity Gain*
- *Supply Resilience*
- *Drought Resilience*
- *Carbon*
- *Flood Risk*

Uncertainty Quantification - DMU





No/Least-Regrets Identification – All Time Vs Temporal



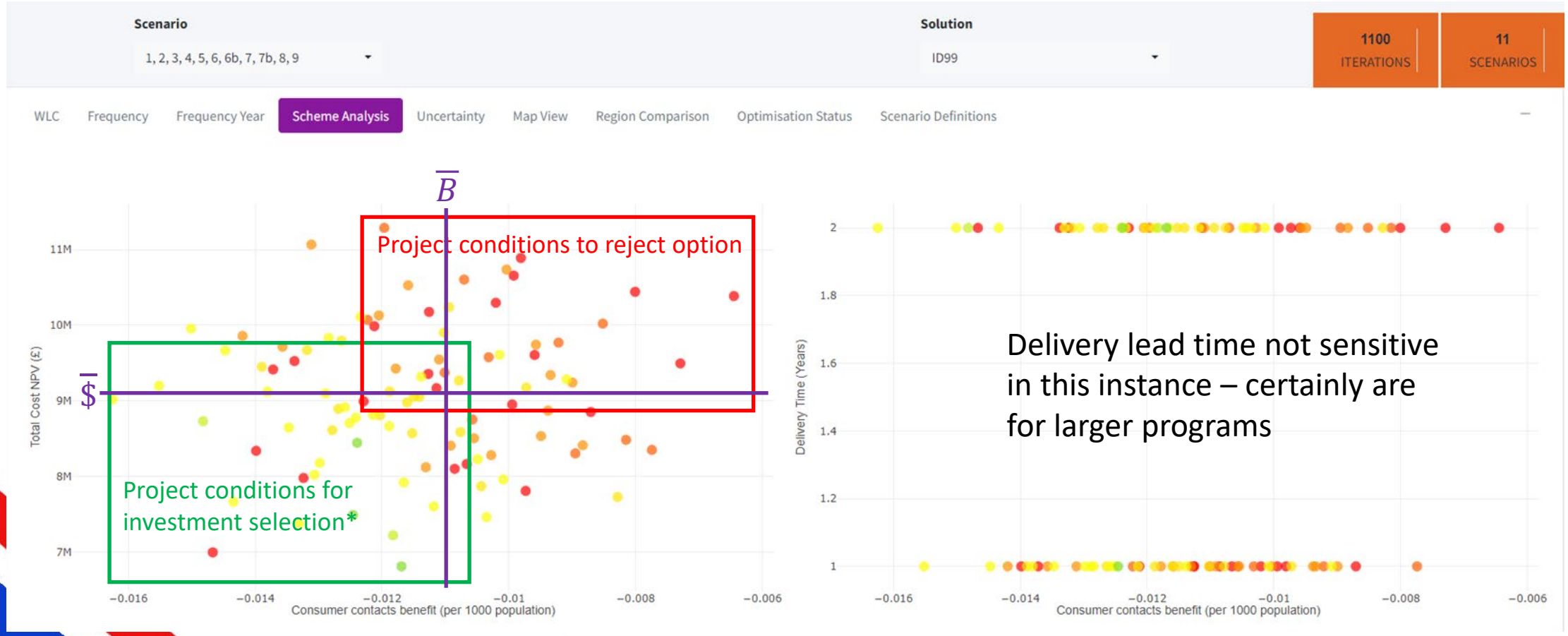
Name	Totals	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049
ID17	100.01	0	0	0	11.73	13.58	0	0	0	12.01	12.87	0	0	0	11.06	11.57	0	0	0	4.55	4.16	0	0	0	11.05	7.43
ID130	100.01	4.73	41.48	47.41	4.19	0	0	0.44	0.21	0	0	0	0	0	0	0	0	1.11	0.44	0	0	0	0	0	0	0
ID114	100.00	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ID115	100.00	0	0	13.23	86.77	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ID116	100.00	4.16	28.75	67.09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ID117	100.00	2.89	31.06	66.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ID118	100.00	37.13	62.87	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ID12	100.00	0	36.08	63.92	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ID13	100.00	0	0	24.93	75.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ID140	100.00	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ID141	100.00	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ID26	100.00	0	0	0	28.45	71.55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ID27	100.00	0	0	1.58	98.42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ID28	100.00	0	0	29.29	70.71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ID30	100.00	0	0	0.74	0.68	0	0	0	0.18	0.46	0	0	0	2.01	1.98	0	0	0	3.24	4.6	0	0	0	42.41	43.7	0
ID31	100.00	0	0	0	30.66	69.34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ID33	100.00	0	0	0	43.32	56.68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ID35	100.00	0	0	0	0	0	0	0	0.09	0.47	0	0	0	7.62	9	0	0	0	9.86	12.77	0	0	0	28.25	31.94	0
ID41	100.00	0	0	0	27.33	72.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ID45	100.00	0	0	0	43.89	56.11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ID50	100.00	0	0	0	36.59	63.41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ID55	100.00	0	0	2.04	97.96	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ID63	100.00	0	0	0	16.27	83.73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ID150	99.90	0	0	0.37	0.64	0	0	0	0.28	0.37	0	0	0	2.12	1.45	0	0	0	5.12	4.81	0	0	0	43.11	41.63	0
ID4	99.78	0	0	0	18.52	17.19	0	0	0	14.81	17.9	0	0	0	11.52	10.87	0	0	0	2.05	1.82	0	0	0	1.99	3.11
ID11	99.76	0	0	0	10.01	14.76	0	0	0	12.2	12.95	0	0	0	11.08	10.93	0	0	0	5.13	5.07	0	0	0	10.12	7.51
ID22	92.37	13.66	1.23	0	0.78	42.36	26.68	1.03	0	0.1	4.37	1.28	0	0	0	0.88	0	0	0	0	0	0	0	0	0	0
ID67	90.18	17.98	9.29	2.91	3.78	9.62	1.96	1.39	0.9	6.39	11.76	9.66	6	0.42	1.73	2.49	3.3	0.34	0	0	0	0.26	0	0	0	0
ID104	89.03	37.17	15.9	4.63	3.16	4.89	1.02	1.82	0	1.49	0.72	0	0	0.22	0.51	1.98	0.73	0	0.42	6.51	5.89	1.97	0	0	0	0
ID56	86.60	0	0	0	0	0	0	0	13.53	15.58	0	0	0	20.79	21.92	0	0	0	6.23	7.05	0	0	0	0.74	0.76	0
ID68	86.28	10.49	6.3	1.38	3.14	3.86	4.09	2.05	0.68	2.47	5.36	4.37	0.93	1.47	7.36	12.19	10.69	7.87	1.58	0	0	0	0	0	0	0
ID57	84.24	0	0	0	0	0	0	0	0	0	0	21.06	9.75	3.62	14.45	23.82	5.74	4.46	0.78	0.33	0.23	0	0	0	0	0
ID9	82.73	0	0	0	0	0	0	0	25.61	35.09	0	0	0	9.98	8.4	0	0	0	1.55	0.64	0	0	0	0.78	0.68	0
ID87	81.17	0	0	11.77	12.54	0	0	0	10.76	10.48	0	0	0	6.21	9.78	0	0	0	7.42	7.5	0	0	0	1.53	3.18	0
ID69	81.15	2.75	2.7	1.87	2.73	6.59	5.9	3.63	1.24	1.83	2.64	4.3	2.32	0.4	1.58	2.75	3.44	1.01	1.32	3.82	13.37	14.96	0	0	0	0
ID129	80.98	0	0	16.57	16.35	0	0	0	6.72	6.13	0	0	0	9.56	11.08	0	0	0	1.19	0.62	0	0	0	6.16	6.6	0
ID61	77.82	0	0	3.4	4.99	0	0	0	16.15	17.12	0	0	0	11.01	12.89	0	0	0	1.99	3.24	0	0	0	3.24	3.79	0
ID19	72.72	0	0	0	0	0	0	0	14.05	17.36	0	0	0	9.73	13.36	0	0	0	4.28	3.64	0	0	0	5.31	4.99	0
ID60	68.24	0	0	3.37	2	0	0	0	18.74	17.92	0	0	0	6.62	9.63	0	0	0	1.75	2.49	0	0	0	3.13	2.59	0
ID132	66.45	1.68	8.47	8.85	1.88	0	0.76	3.37	3.13	0.87	0	0.67	6.83	9.63	0.84	0	1.32	6.84	7.7	0.85	0	0.11	1.19	1.46	0	0

Scheme Choice Perspectives – ‘Coin Toss’ Option Benign Scenario (RCP2.6)

Scheme Choice Perspectives – ‘Coin Toss’ Option ‘Most Likely’ Scenario (RCP6)

Under an adverse scenario, greater tolerance acceptable, however general trend towards higher benefit

Scheme Choice Perspectives – 'Coin Toss' Option Against All Futures

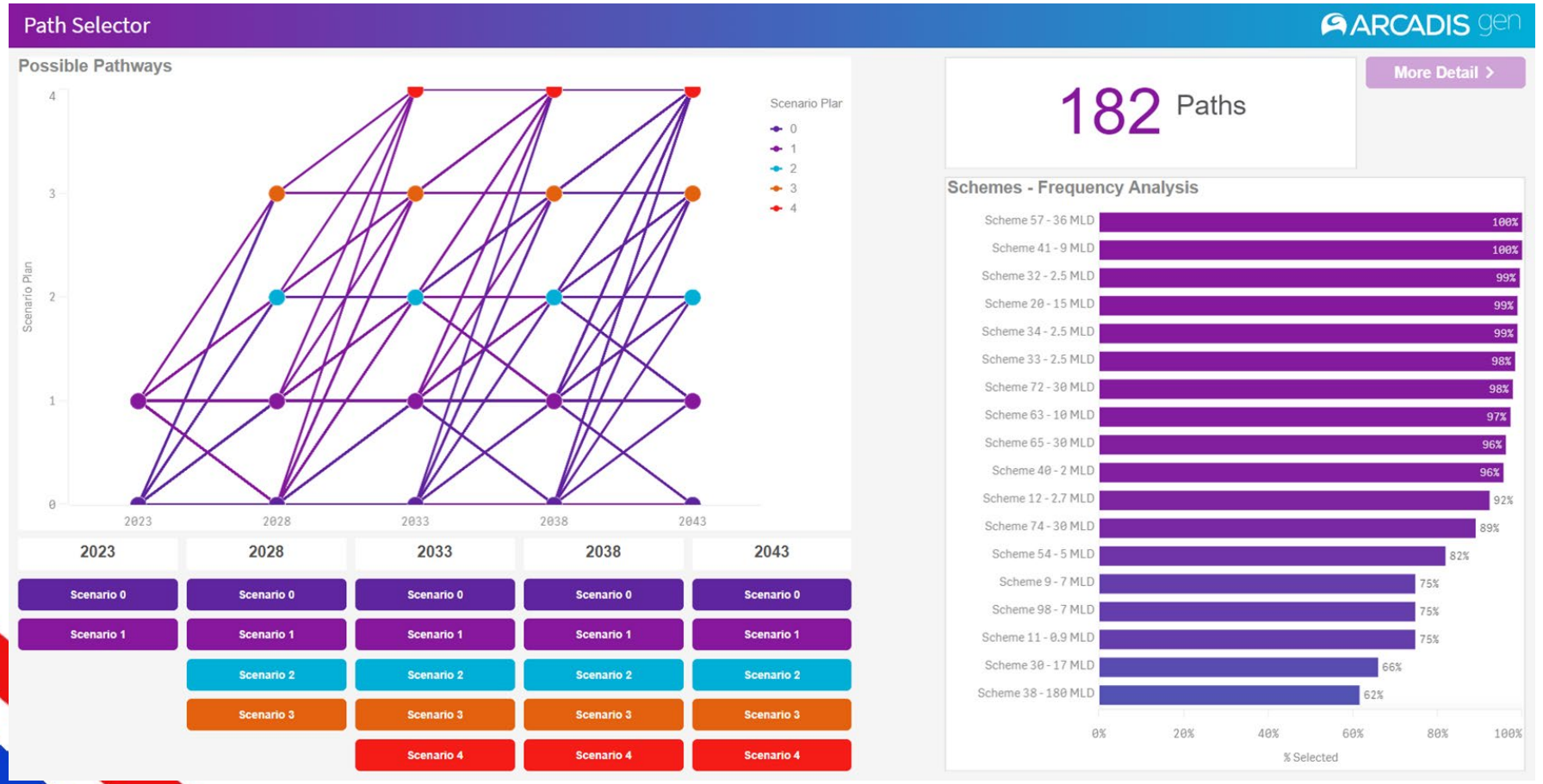


*interesting that a CBA lens isn't always the right choice in an uncertainty paradigm

Scheme Choice Perspectives – Benefit Lead Time Dependency

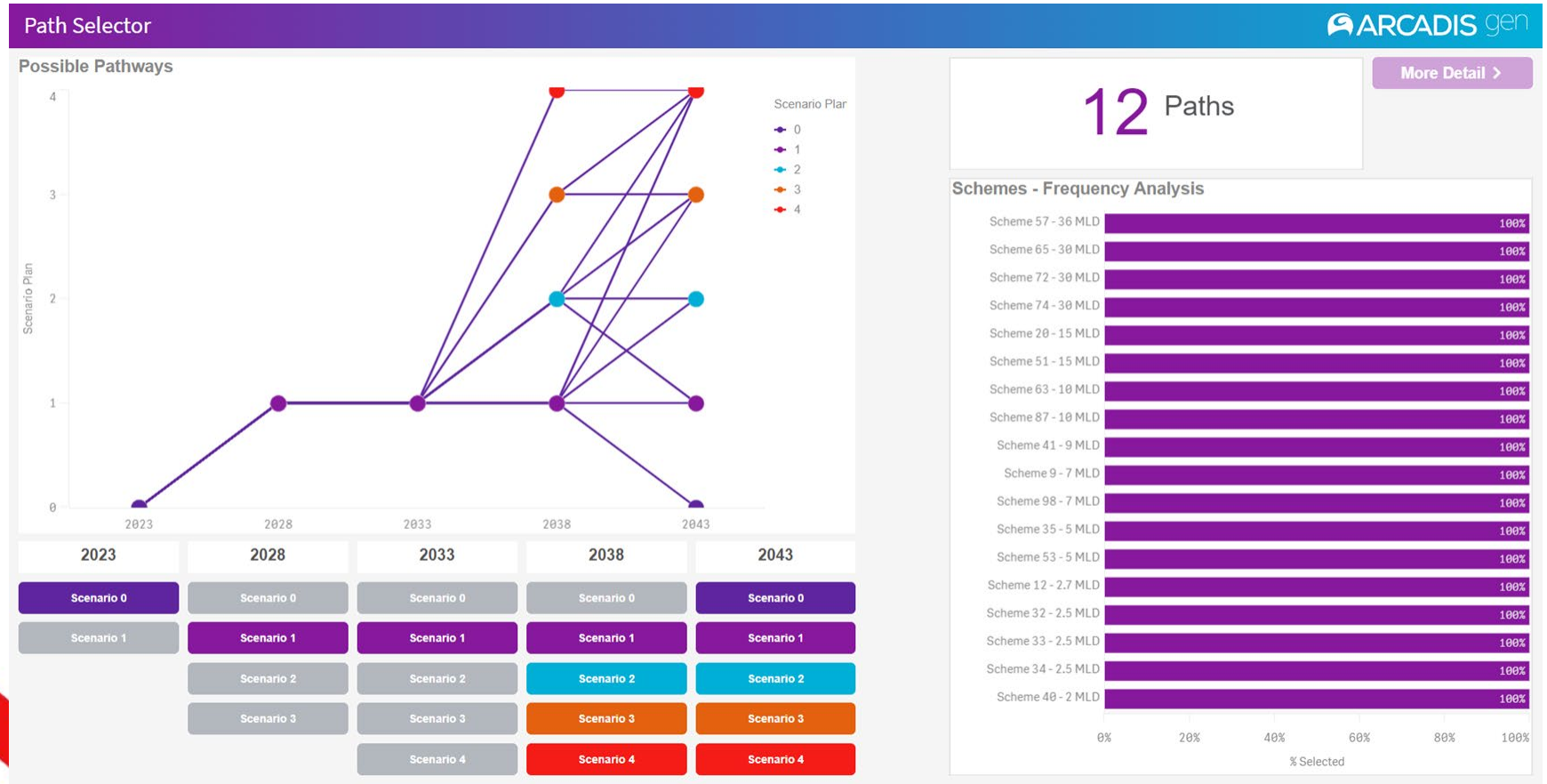
Again, how do we navigate all this additional information and insight?

Consider all possible combinations?



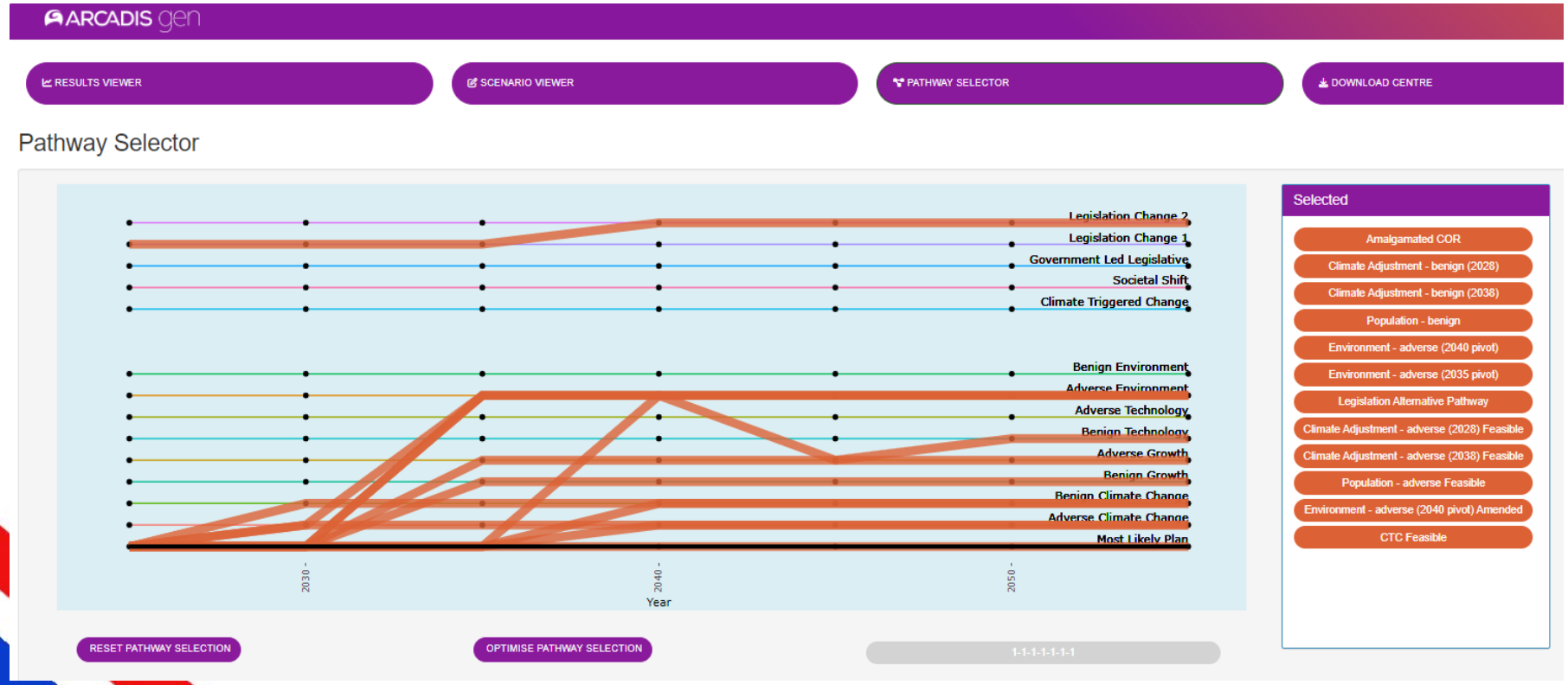
- It is possible to approach this problem programmatically;
- This example we looked at all 182 optimized ‘legal’ pathways, through ~50 alternate futures
- However, this generated more information that doesn’t necessarily steer you towards **<u>what to actually do…</u>**

Home in on plausible futures?



- This leads to a need for more digestible ‘route’ plans
- The drawback here was the abstract nature of pathway naming…

We have found a mapping hierarchy to be most effective…



- Mapping investment stream scenarios to **digestible pathway categories** allows us to pose easier to understand planning questions e.g. what if there is a policy change in 3 years?, what if I defer the challenge of adverse climate on water supply?
- Defining the pivots, or deltas from the **most likely pathway** produces rich planning insights – such as **swings in large capital project timings** – both **deferral and expedition**

For Example… Pivot to an Adverse Climate Change Scenario

ARCADIS gen

ABOUT

RESULTS VIEWER | SCENARIO VIEWER | PATHWAY SELECTOR | DOWNLOAD CENTRE

Pathway comparison | Pathway detail | Gantt view | Popularity detail | NPV | Diagnostics

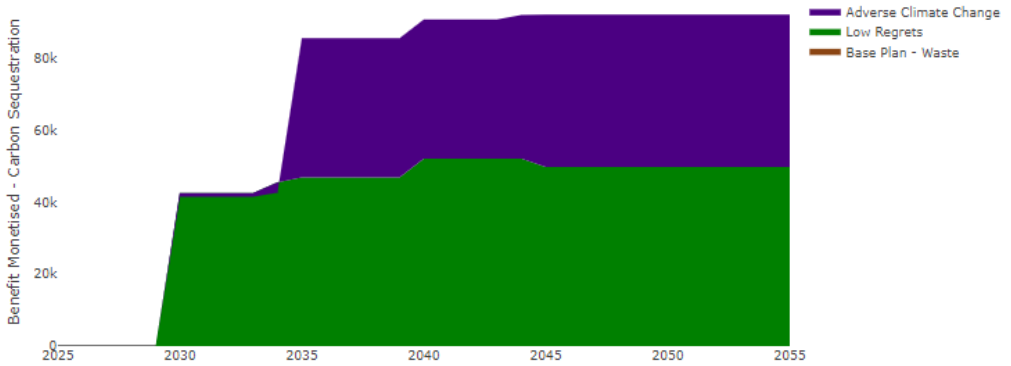
PATHWAY

Adverse Climate Change

UME

Base Plan - Waste, Water_Resilience

Combined Plan - Benefit Monetised - Carbon Sequestration

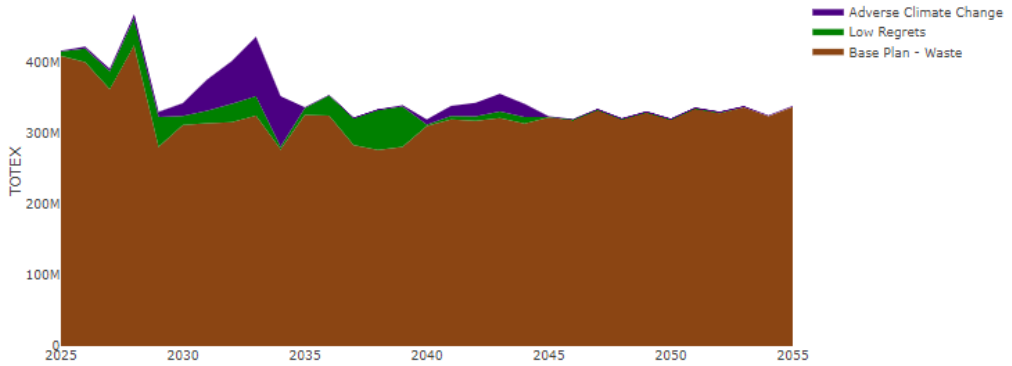


CHANGE CHART

Download CSV

Model	2025-2029	2030-2034	2035-2039	2040-2044	2045-2049	2050-2054	2055-2059
Base Plan - Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Candidate	0.00	-7,098.82	194,065.20	195,251.50	212,055.25	212,055.25	42,411.05
Low Regrets	0.00	216,130.38	234,694.80	260,702.15	249,213.95	249,213.95	49,842.79
Total	0.00	209,031.56	428,760.00	455,953.65	461,269.20	461,269.20	92,253.84

Combined Plan - TOTEX

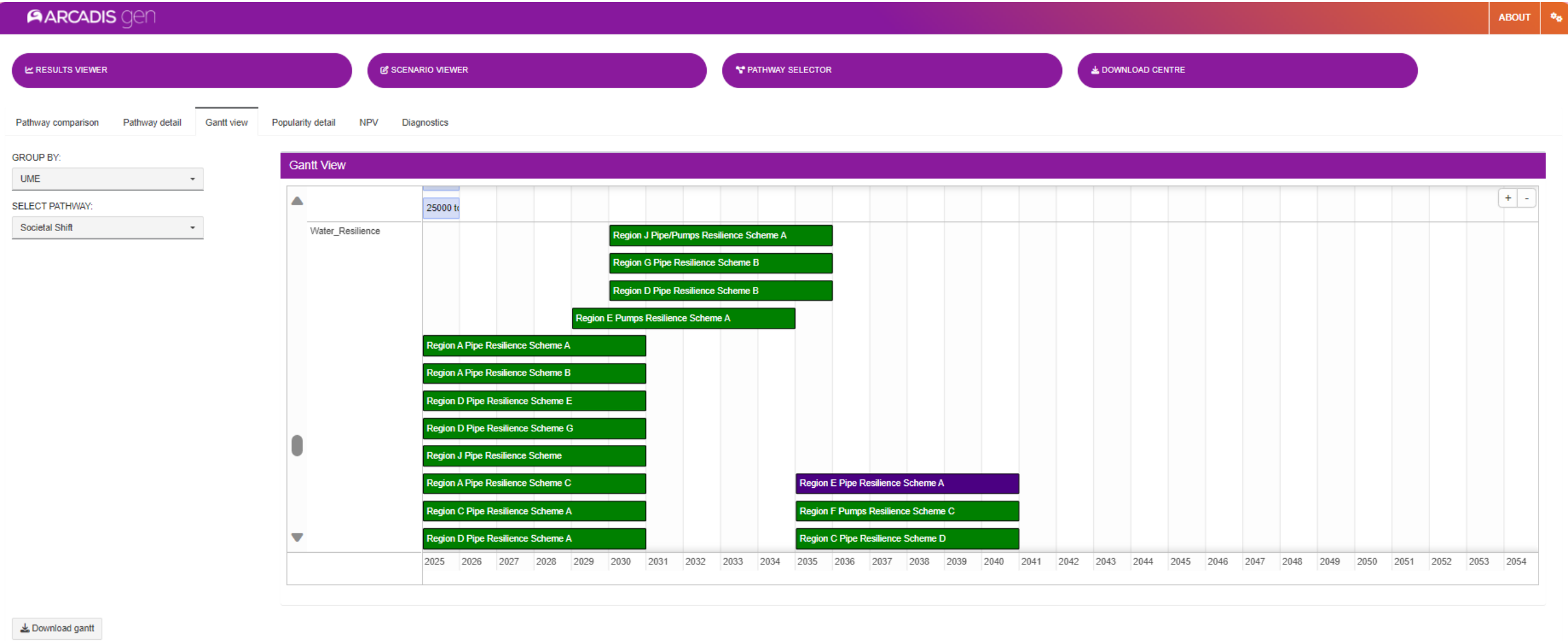


CHANGE CHART

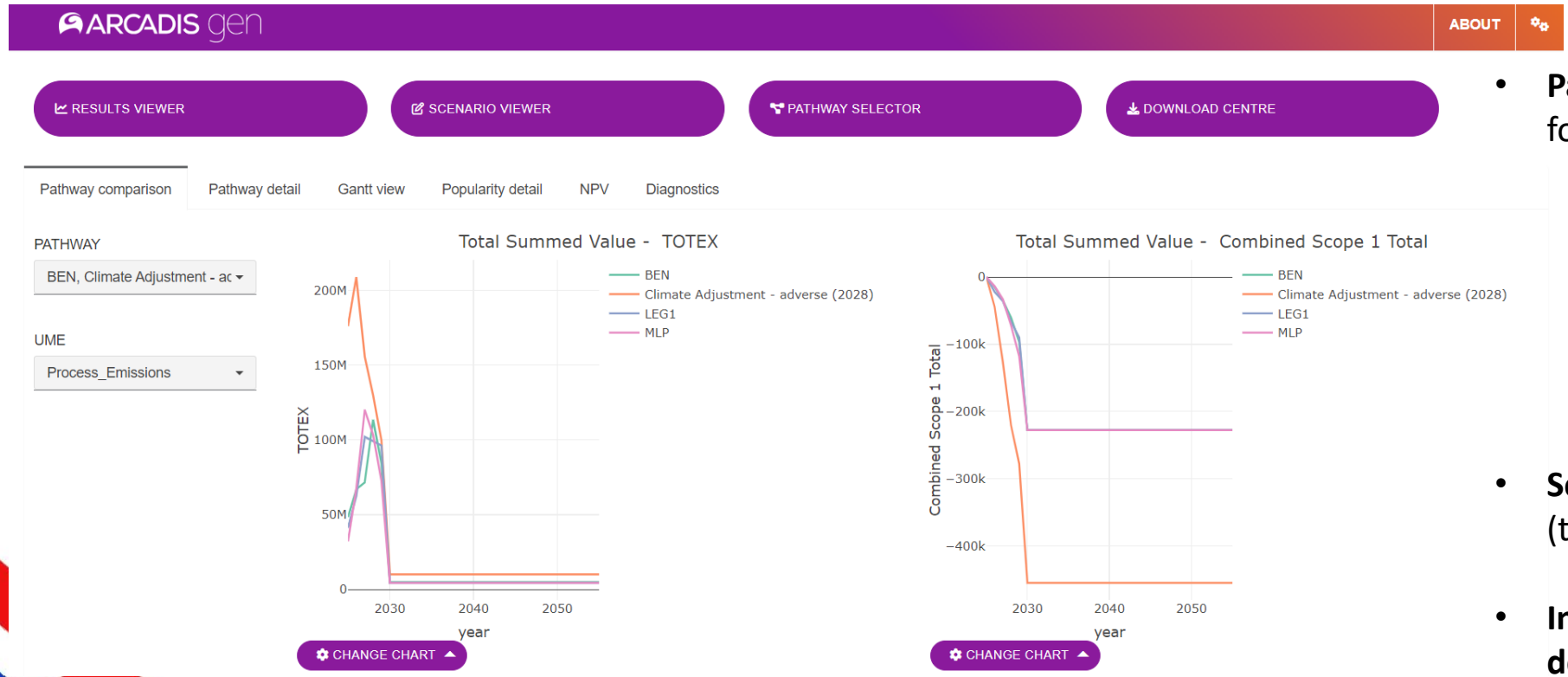
Download CSV

Model	2025-2029	2030-2034	2035-2039	2040-2044	2045-2049	2050-2054	2055-2059
Base Plan - Waste	1,881,658,966.21	1,549,088,969.47	1,495,717,439.41	1,587,101,908.65	1,627,232,693.65	1,647,636,058.65	338,178,164.73
Candidate	20,331,167.80	277,966,683.20	6,149,875.65	84,006,512.35	5,142,855.00	5,142,855.00	1,028,571.00
Low Regrets	131,338,157.35	86,996,957.99	189,874,131.50	32,358,000.50	3,282,350.50	3,282,350.50	656,470.10
Total	2,033,328,291.36	1,914,052,610.66	1,691,741,446.56	1,703,466,421.50	1,635,657,899.15	1,656,061,264.15	339,863,205.83

Gantt Representation… Additional Pipe Resilience Scheme Brought Forward



Example Process Emissions Pathway Comparison



- **Pathway TOTEX** profile comparisons for:
  - 'Most Likely Pathway' (MLP)
  - Alternate **Legal Policy Shift** assumption
  - **Climate adjustment extremity** case
  - **Benign environmental** pathway
- **Scope 1 process emissions** ($tCO_2e/yr.$)
- **Investment sensitivity to net-zero deadline** quantified; some intuitive movement between alternative pathways

Conclusions, Outcomes, Next Steps…

Conclusions

1. AIP optimization models with significant input and external driver(s) uncertainty can still provide rich investment decision making insight, despite these broad range uncertainties
2. The least-cost plan is an important benchmark, however has the potential to contain high regret decisions, if not interrogated with advanced analytics techniques
3. It is possible to identify the looming ‘big ticket’ investments through an adaptive planning approach – further, even if commitment cannot be reached, feasibility studies can (and are) being triggered by these analyses

Conclusions, Outcomes, Next Steps…

Outcomes

- **Greater Certainty** Around Investment choices
  - Ability to quantify the impact of pathway changes e.g. acceleration, or deferral of sustainability challenges
- **Business Planning Benefits** to future scenario planning – 'codifying' of **multiple stakeholder** views of uncertainty
- **Real Business/Organization**, and ultimately **service user benefits**
  - For Example - in long term water resources planning (25-80 year SDB), this approach has supported a major Green Recovery Program – C$940m/$690m capital program, expediting capacity schemes with added social and environmental benefits

Conclusions, Outcomes, Next Steps…

Next Steps - further work to do, and ongoing in:

- **GHG Process Emissions** – **Net Zero** Planning
  - Some UK clients pushing for 2030 net zero deadline
  - Australian clients working towards similar timeframes
- **Adaptive Planning** for Assets in **proximity to the sea** – Ports, Water Treatment plants, Saline Intrusion
- **Water Resilience** – we are seeing a significant growing demand for adaptive planning in this area
- **Drinking Water Quality** – we are looking at flushing strategies to reduce customer quality complaints (Regulatory measure in the UK) with our clients
- **New Wind Farm Location Selection** – we are helping to remove investment bias by applying uncertainty to MCA metrics; we are also looking at the applicability to offshore connections
- **Healthcare Organization** risk reduction – across a large buildings portfolio