Climate Resilience Training: Training report

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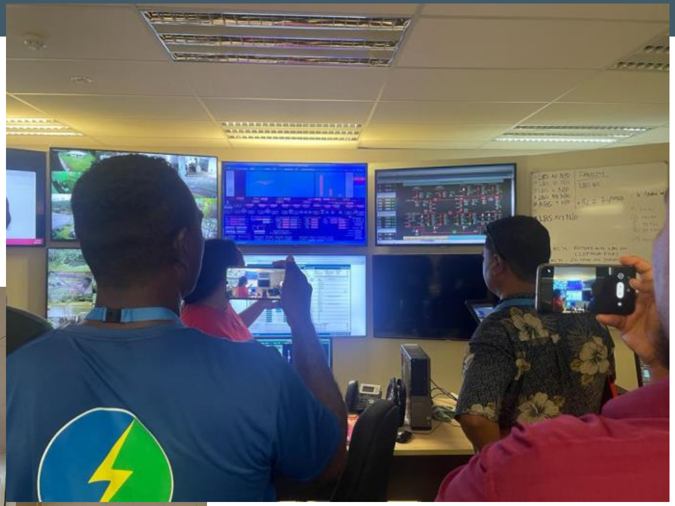
Training report

- As part of this assignment ECA provided training to 24 participants from the PPA member utilities from 7-8 February in Apia, Samoa
- The participants came from a diverse range of utilities of different sizes, covering both the North and South Pacific and with a diverse range of hazards facing them
  - The pool of participants included a range of staff ranks, including 3 CEOs, several business managers and engineers
  - This diversity led to fruitful discussions between all participants
- EPC kindly organised two site tours, including to a hydro power plant and their control room, which were well received by participants
- The training was well received by participants, with high engagement throughout and many noting that they saw a real use for the tools developed in their organisations
- Participants also made the most of the opportunity to engage with other participants and discuss their different and shared challenges and insights



Agenda

Day 1 – Tuesday, 7th Feb	Day 2 – Wednesday, 8th Feb
Introductions	Welcome and re-cap of day 1
Session 1 – Overview of climate risks and natural disasters affecting Pacific Utilities	Session 4 – Introduction to Resilience Viability Tool
Session 2 – Discussion on climate resilience and disaster readiness	
Coffee break	Coffee break
Session 3 – Introduction to Resilience Assessment Tool	Practical exercises on use of Resilience Viability Tool
Practical exercises on use of Resilience Assessment Tool	Final discussion and Q&A
Lunch	Lunch
Site visit 1 – Details to be provided by EPC	Site visit 2 – Details to be provided by EPC

Climate Resilience Training: Day 1

7 February 2023

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in business

60
assignments annually

10+ years
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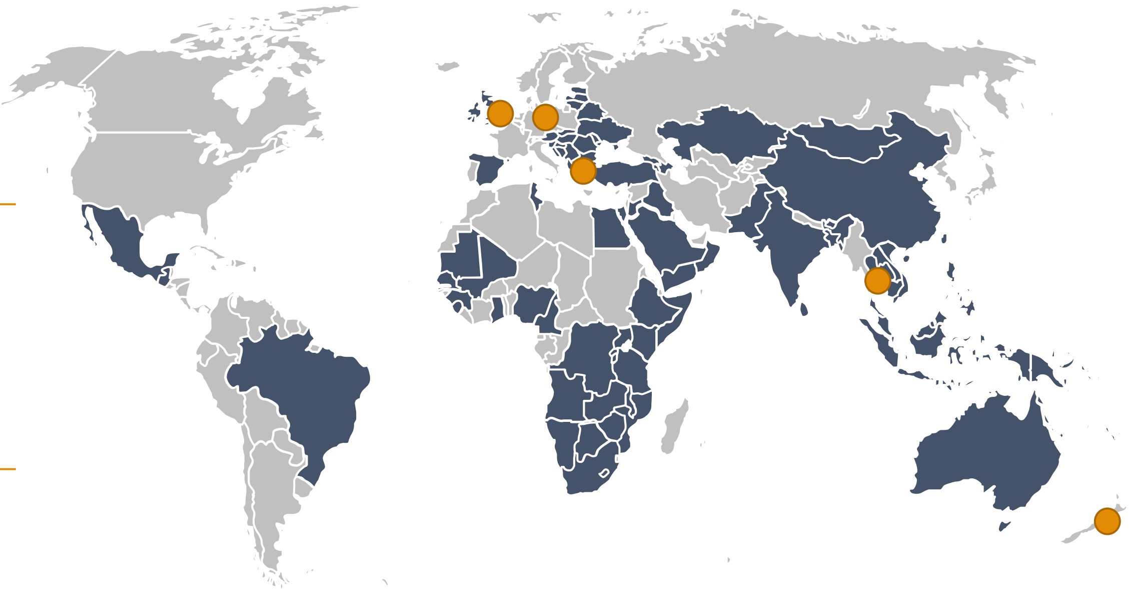
Economists

100%
Employee owned

45
Regulators advised

3
Offices
London, Athens, Berlin + Staff in Bangkok and NZ



70
Countries worked in

25
National utilities advised

- Guide to investing in RE generation in the Pacific (IFC)
- E-mobility roadmap and framework
- Rooftop solar and distributed generation policies
- Cost-of-service and tariff design studies
- Climate resilience investment plans

ECA provides economic consulting advice on infrastructure services to governments, regulators, and investors worldwide

Overview of assignment

- ECA & SMEC were contracted under the World Bank *Sustainable Energy Industry Development Project* to provide technical assistance to enhance the energy resilience among Pacific Utilities
- Original phase in 2019-2020 aimed to provide technical, financial, and environmental advice on resilience
  - Included the development of a Resilience Viability Tool to help utilities assess the economic viability (cost-benefit) of resilience measures
- Assessment for three representative utilities
  - Large – Papua New Guinea
  - Medium – Samoa
  - Small – Tuvalu
- Follow-on assignment in 2022-2023 to develop a tool to help Pacific utilities assess their current climate resilience
  - Identify areas that need investments
  - Benchmarking over time and across countries

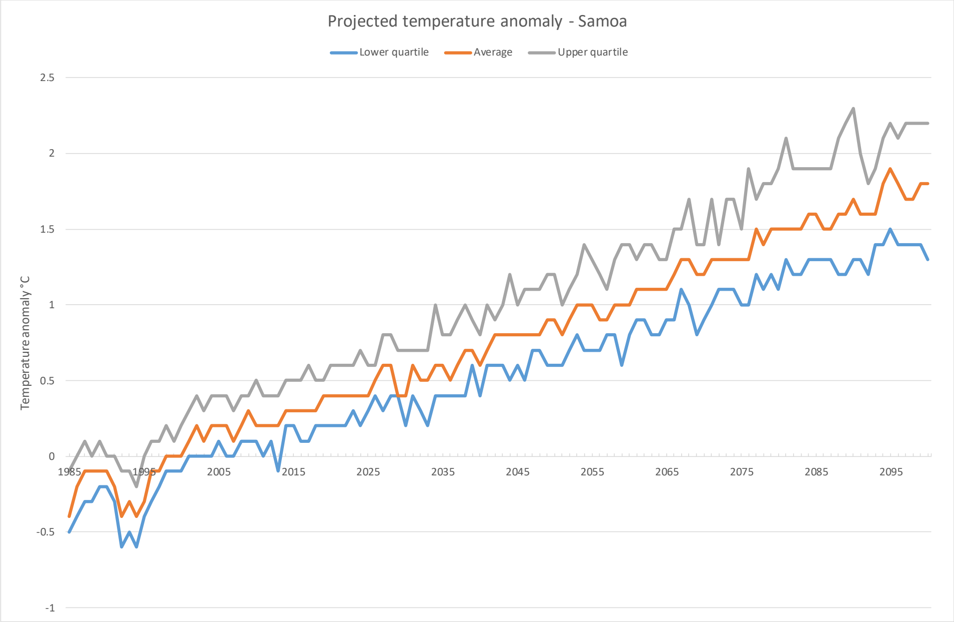
<u>Objectives of original phase</u>

- Mapping vulnerable power infrastructure subject to impacts of climate and natural disasters
- Vulnerability assessment of physical assets and energy supply at three target utilities
- Recommended technical solutions needed to enhance resiliency of three power systems
- Recommended investment plans and prioritising pipeline of climate resiliency projects

Session 1 –
Overview of climate risks and natural disasters affecting the Pacific Island Power utilities

Climate and disaster resilience – a priority for the Pacific utilities

- Pacific utilities are particularly exposed to a range of extreme weather events and natural disasters
- Global climate change is expected to increase the frequency and intensity of many of these hazards
  - At the same time, reliance on electricity will continue to grow
- Urgent need to increase the climate and disaster resilience of the energy infrastructure
- 2021-2030 Framework for Energy Security and Resilience in the Pacific (FESRIP) highlights urgency of supporting the development and management of climate-resilient and disaster-resilient energy infrastructure
  - Resilience also a focus area of donors and international organisations



Considerations to improve the climate and disaster resilience

- Pacific utilities should take steps to improve their climate and disaster resilience
- Ideally, they should ideally develop their own *Climate Resilience Plan*
  - Should be updated regularly
  - Climate resilience assessments and considerations should be incorporated into the power development plan process
- Need for this *Climate Resilience Plan* to identify key risks and areas for prioritised investment
  - Investments to improve resilience can be expensive or resource-heavy, meaning they may need to be prioritised
- We have set out a set of principles/process to follow in developing such a plan

Principles to improve climate resilience of Pacific utilities

Identify risks of extreme natural events (climate and disaster related)
- Understand the hazards exposed to and the potential impacts

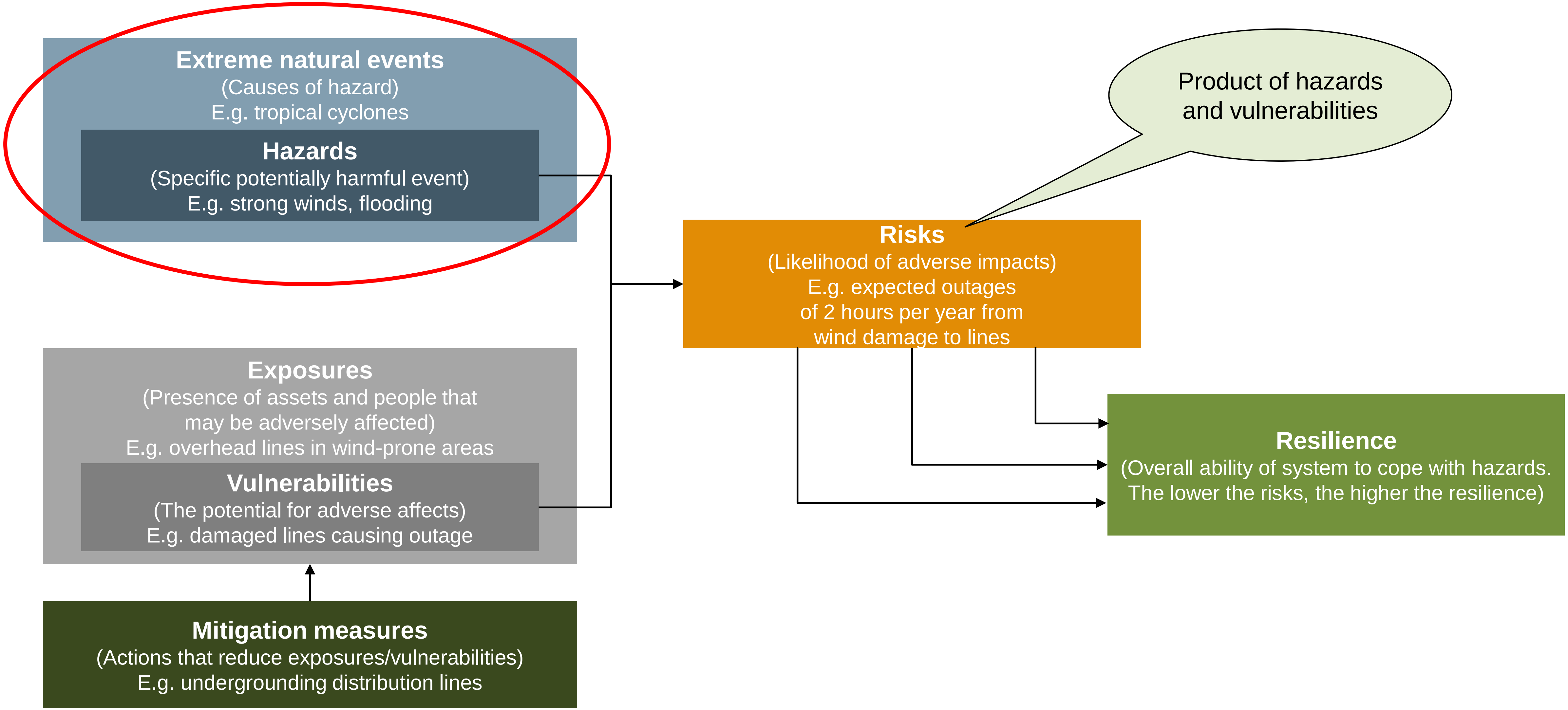
Identify resilience measures that could be implemented
- How can these potential impacts be (partially) mitigated

Screen and select resilience measures
- Determine the technical and economic viability of identified resilience measures

Monitor and evaluate measures
- Ensure better responsiveness to potential threats

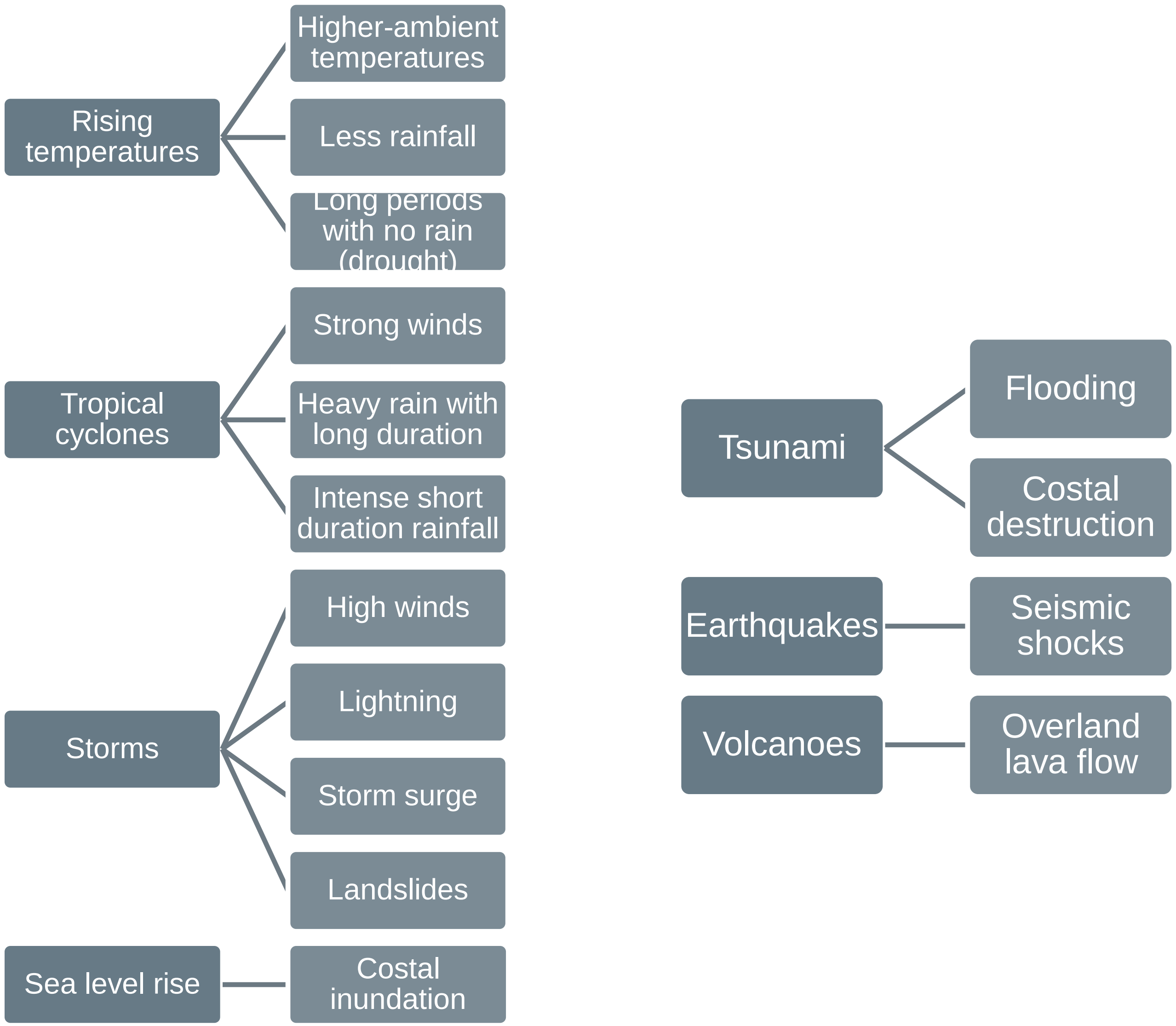
Put in place financial protection
- Eg. Self-insurance programmes

Framework for the (sometimes confusing) terminology surrounding resilience

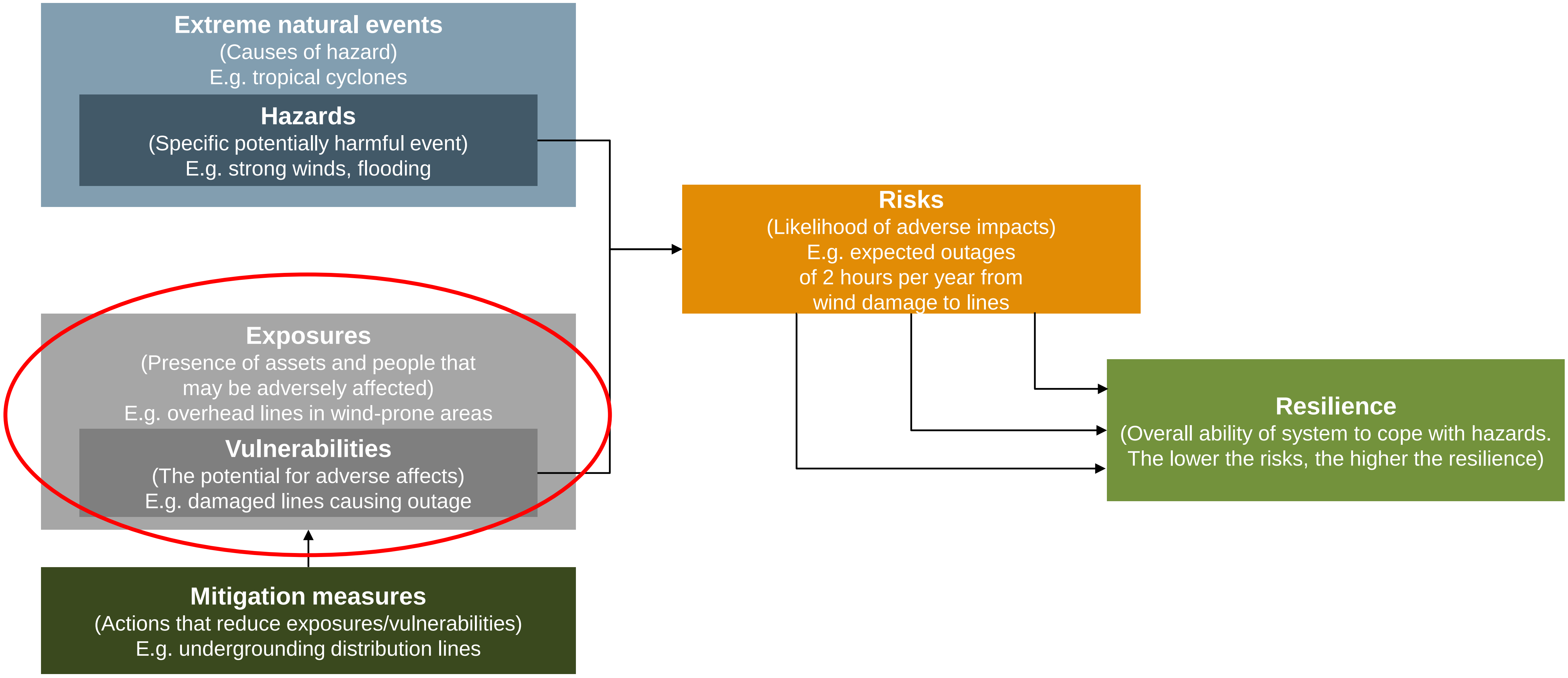


Hazards

- Extreme natural events give rise to hazards, which are a **potentially harmful event**
- These can be split into climate and weather-related events and geophysical events
  - Note that Pacific utilities may also be affected by other hazards, such as those caused by humans (eg. terrorism, cyber-attacks, or a pandemic)
- Some hazards may be short-lived and temporary (eg. high winds) while others may be gradual and lasting (drought or costal inundation)
- Hazards vary by both **frequency** and **intensity**



Framework for the (sometimes confusing) terminology surrounding resilience



Exposures and vulnerabilities

- **Exposure**: Assets or aspects of operations that may be impacted by a hazard (eg. overhead lines in wind exposed areas)
- **Vulnerability**: Potential for adverse outcomes (overhead lines damaged, impacting supply to customers)
- Note that hazards do not only impact assets but **also day-to-day operations** (eg. maintenance may be disrupted by flooding)
  - Don't restrict focus to common aspects (eg. overhead lines or transformers)
  - Consider full value chain – from generation through to retail
- Potential impacts of hazard on the system can vary
  - Some impacts may be small and short-lived
  - Others may be large and have a significant impact
- Overall vulnerability can be influenced by mitigation/resilience measures

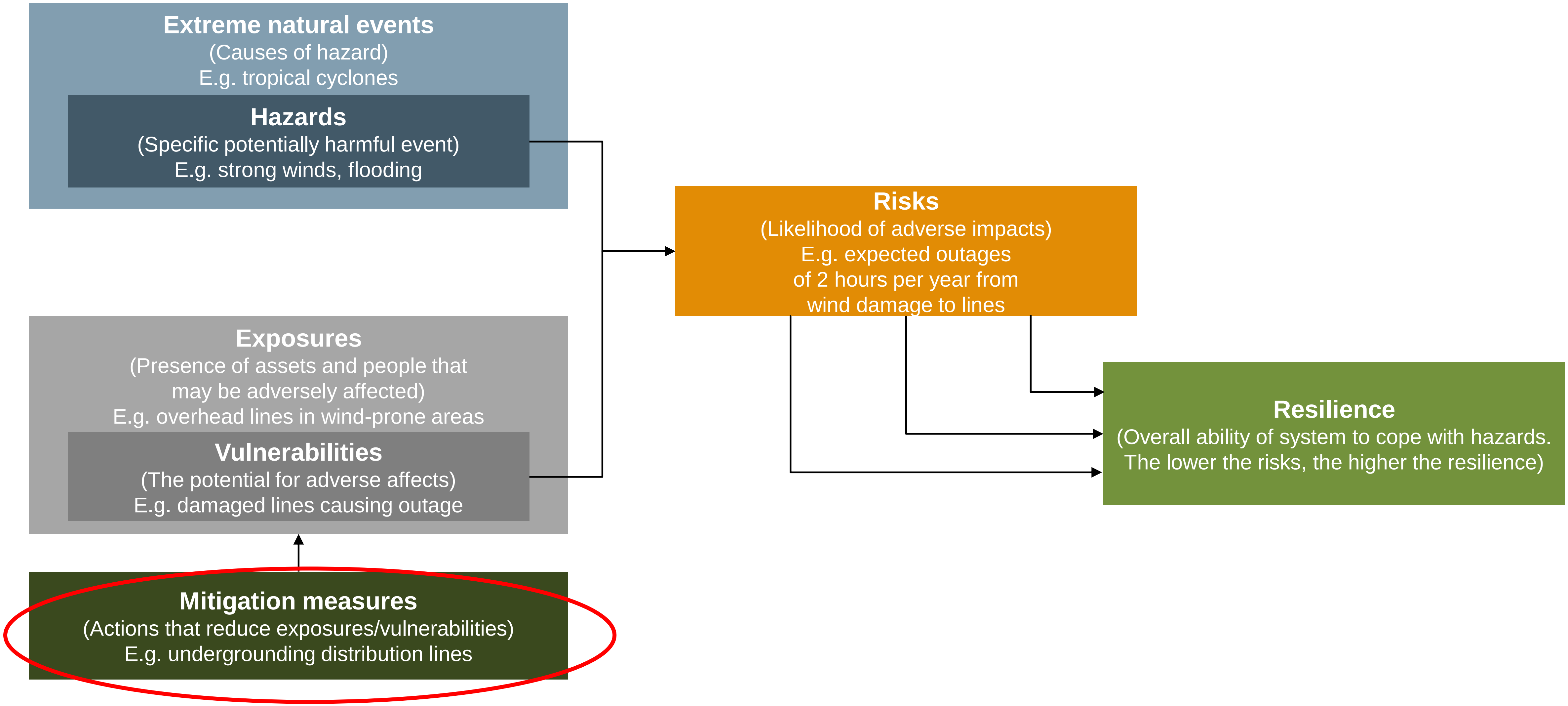
Hazard: Strong winds
Exposure: Overhead networks
Potential impacts:

- Overhead equipment is damaged or destroyed
- Falling trees bring down overhead conductors
- Wind turbines are damaged or destroyed

Hazard: Coastal inundation
Exposure: Ground mounted equipment
Potential impacts:

- Flooding causes faults
- Water damage requires equipment replacement

Mitigation measures



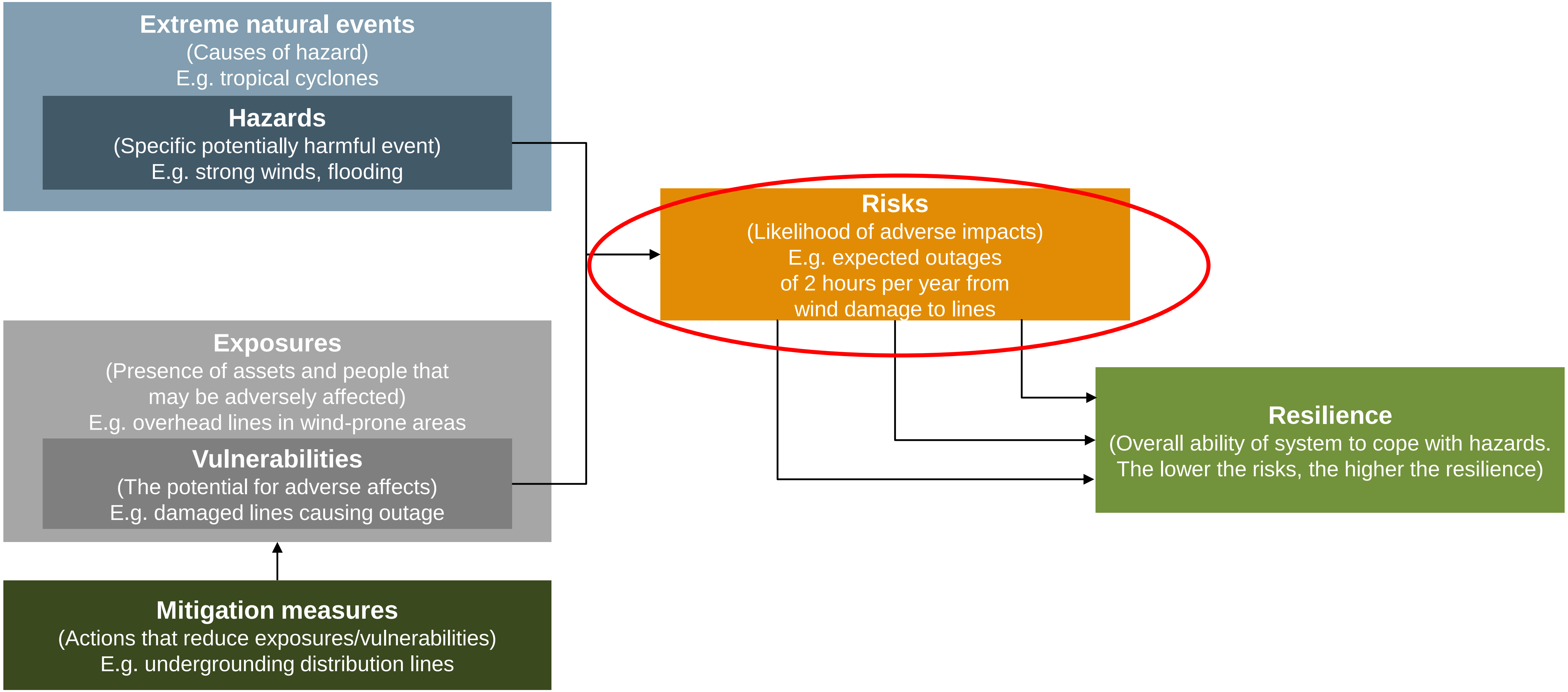
Mitigation measures

- Pacific utilities can implement a range of mitigation measures to reduce their vulnerability to hazards
- Includes both capital investments as well as changes to operating procedures
- Some measures may be very expensive and difficult to implement (or spread over a long time), while others can be implemented relatively quickly
  - Distinction between incorporating resilience in new projects and planned replacements vs bringing forward upgrades to improve climate resilience
- Ability to learn from each other on what measures are successful

Hazard: Strong winds
Exposure: Overhead networks
Potential mitigation measures:
- Design overhead equipment for applicable maximum wind speeds
- Consider underground vulnerable sections of overhead power

Hazard: Coastal inundation (from sea level rise)
Exposure: Ground mounted equipment
Potential mitigation measures:
- Mount equipment above ground
- Use water-proof enclosures
- Locate key assets in higher areas

Framework for the (sometimes confusing) terminology surrounding resilience



Risk

- Risk is the **likelihood** of a hazard event having an **adverse impact**
- Hazard is an event that *has the potential* to cause damage
- Risk consider *how likely* it is that it will cause damage
  - Combination of hazard and vulnerability
- Risk **may change over time**:
  - It can decrease because:
    - Hazards become less frequent or less severe
    - Mitigation measures reduce the vulnerability
  - It can increase because
    - Hazards become more frequent or more severe (eg as a result of global climate change)
    - Increase reliance on electricity or an expansion of the system increases exposures and vulnerability

Tools to support Pacific utilities in improving their resilience

Identify risks of extreme natural events (climate and disaster related)
- Understand the hazards exposed to and the potential impacts

Identify resilience measures that could be implemented
- How can these potential impacts be (partially) mitigated

Screen and select resilience measures
- Determine the technical and economic viability of identified resilience measures

Monitor and evaluate measures
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Put in place financial protection
- Eg. Self-insurance programmes

Resilience Assessment Tool
Initial 'high-level' assessment to identify climate-related risks and potential resilience measures

Resilience Viability Tool
To help assess the economic viability of identified resilience measures and understand the trade-off of higher costs vs reduced risk

Session 2 –
Discussion on climate resilience and disaster readiness

Group discussions

- Split into groups of 5 people and discuss the following questions
- Be prepared to present your findings to the audience

1) What impacts have extreme natural events had on your system in the past?

2) What mitigation activities have you already implemented that have worked well?

3) What risks are you most worried about going forward?

4) What key mitigation activities do you think are still needed? And how are you going to make them happen?

5) How do you (if at all) incorporate climate resilience into your planning?

Session 3 –
Introduction to the Resilience Assessment Tool

Objective of the Resilience Assessment Tool

Assess current resilience

- Act as tool to support Pacific utilities in assessing their current level of resilience
- Determining which hazards post the greatest risk and which aspects of system are most vulnerable

Evaluate impact of mitigation measures

- Assess impact of introducing mitigation measures on resilience relative to status quo

Track resilience over time

- Updating tool over time allows utility to track how resilience changes over time

Benchmark resilience

- Compare resilience relative to peers
- Subject to thorough review of inputs and ensuring they are set following standard principles

Overview of tool

Step 1: Check hazard ratings

Country exposure to hazards

How severe (frequent and intense) are the hazards that the country is exposed to?

Pre-populated in model, can be changed by user

Measure of severity of hazard for the country: 0 = never occurs, 10 = occurs with very high frequency and intensity

Step 2: Input impact ratings

Potential impacts on power system

How severe is the impact of each hazard event on the power system, if no mitigation measures are taken?

User inputted

Measure of severity of potential impact of hazard event on power system, without mitigation: 0 = no impact, 10 = severe impact

Step 3: Input mitigation ratings

Mitigation measures

What has been done to reduce the impact of hazards on the power system?

User inputted

Measure of the extent to which potential impacts of each hazard have been mitigated: 0%=not at all, 100%=completely

Step 4: Review calculated vulnerability ratings

Vulnerability of power system

How severe is the impact of each hazard event on the power system, after mitigation measures are implemented?

Calculated as impact rating multiplied by 1 minus mitigation rating

Measure of severity of impact of hazard event on power system, with mitigation: 0 = no impact, 10 = severe impact

Step 5: Review calculated risk scores

Risk score

What is the risk of each type of hazard to the power system, after combining the hazard severity and potential/expected impacts?

Calculated as hazard rating multiplied by vulnerability rating

Step 6: Review calculated overall risk score

Overall risk score

What is the overall level of risk to the power system, after combining the severity of different hazards with their expected impacts?

Calculated as the average of risk scores across all hazards

Step 7: Review calculated resilience indicator

Resilience indicator

What is the power system's overall resilience to climate events and natural disasters?

Calculated as 100 minus the overall risk score

1) Determine hazard rating

- Identify the hazards to which the country is exposed to
- Determine how severe these hazards are
  - Combination of frequency and intensity
- Expressed as a ***hazard rating***
  - 0= Hazard does not occur
  - 10=Most severe
- Model is pre-populated with information on hazards for Pacific countries and territories
  - Can be updated by users

Hazard rating	Frequency	Intensity
0	Does not occur	N/A
1	Very rare occurrence	Very low
2	Rare occurrence	Low
3	Occasional occurrence	Low
4	Combination of either frequent event with low intensity, or intense event with relatively low frequency	
5		
6		
7		
8	Frequent occurrence	
9	Very frequent	
10	Extremely frequent	Intense

2) Input impact ratings

- Identify potential areas of impact for each hazard, if no mitigations are in place/taken
- After identification, determine the severity of the potential impact
- Note that one hazard can have different impacts – need to provide an impact weighting to reflect the relative weight of each impact on the power system as a whole
- Potential impacts can vary significantly across utilities and over time
  - For example, some hazards (eg drought) may have adverse impacts on hydro generation

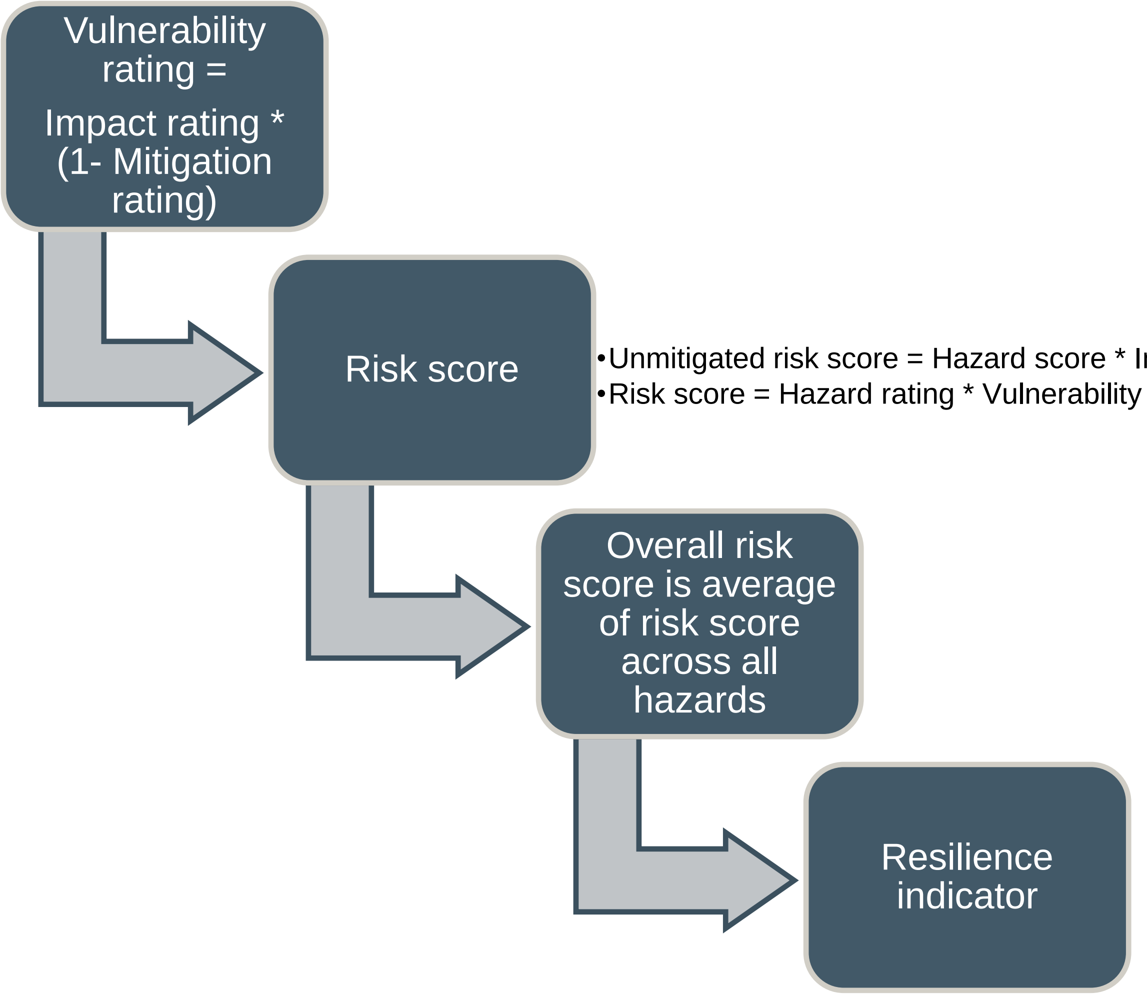
Potential impact rating	Impact	Affected Area	% of Customers Affected	Expected Restoration Time Hours
0 (best case)	None	None	0	na
1	Minimal	1 Customer with no power	≤ 1	≤ 0.5
2	Minor	≤ 10 Customers with no power	≤ 2	≤ 1
3	Minor	1 LV Feeder tripped	≤ 2	≤ 0.5
4	Significant	≥1 LV Feeders tripped	≤ 5	≤ 1
5	Significant	1 MV Feeder tripped	≤ 10	≤ 0.5
6	Serious	≥1 MV Feeders tripped	≤ 20	≤ 1
7	Serious	≤ 50% of generation unavailable	≤ 50	≤6 hours
8	Severe	≥ 50% of generation unavailable	≥ 50	≥6 hours
9	Severe	Entire network blackout	100	≤6 hours
10 (worst case)	Severe	Entire network blackout	100	≥6 hours

3) Input mitigation ratings

- Identify which mitigation measures are in lace to reduce potential impact
- Determine to what extent these measures mitigate the potential impact of the hazard

Mitigation rating	Mitigation result
100 % (full mitigation)	Potential impact can be fully mitigated with no consequence to normal power supply
90 %	Potential impact can be mostly mitigated with minimal effect on normal power supply
80 %	Potential impact can be partly mitigated with minor effect on normal power supply
70 %	Potential impact can be partly mitigated with some effect on normal power supply
60 %	Potential impact can be partly mitigated with significant effect on parts of normal power supply momentarily
50 %	Potential impact can be partly mitigated with significant effect on parts of normal power supply for short period
40 %	Potential impact can be partly mitigated with serious effect on parts of power supply for short period
30 %	Potential impact can be partly mitigated with serious effect on entire power supply for say 1 hour
20 %	Potential impact cannot be mitigated resulting in severe effect on entire power supply for say ≤ 5 hour
10 %	Potential impact cannot be mitigated resulting in severe effect on entire power supply for say 1 day
0 % (no mitigation)	Potential impact cannot be mitigated resulting in severe and prolonged effect on entire power supply

Review calculated scores



- Unmitigated risk score = Hazard score * Impact rating
- Risk score = Hazard rating * Vulnerability rating

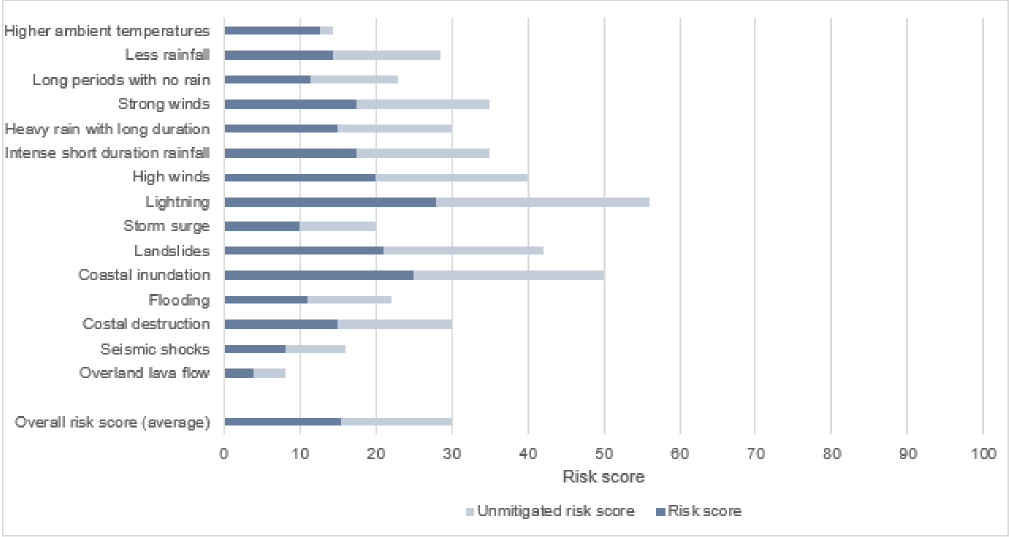
- Inverse of overall risk score
- Higher score indicates a higher resilience

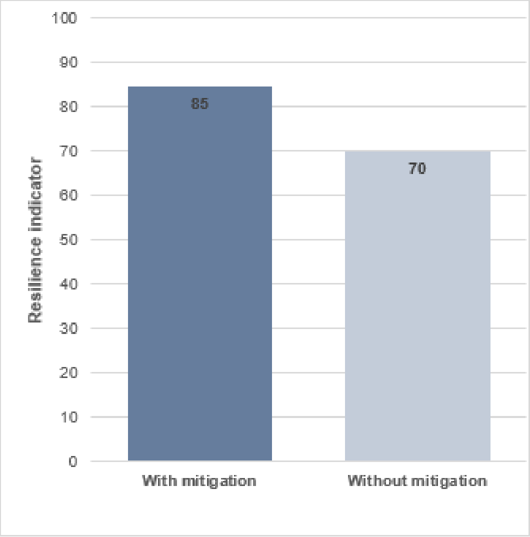
Summary of key parameters

#	Aspect	Input type	Description	Scale
1	**Hazard rating**	Pre-populated in model for Pacific countries and territories, but can be changed by user	Measure of severity of hazard for the country, which is combination of frequency and intensity	Scale 0-10: 0= never occurs 10= occurs with very high frequency and intensity
2	**Impact rating**	User inputted	Measure of severity of potential impact of hazard on power system	Scale 0-10: 0= no impact 10= severe impact
3	**Mitigation rating**	User inputted	Measure of the extent to which potential impacts of each hazard have been mitigated	Scale 0-100%: 0%= not at all 100%= completely mitigated
4	**Vulnerability rating**	Calculated as impact rating multiplied by 1 minus the mitigation rating	Measures severity of impact of hazard on power system after mitigation is taken into account	Scale 0-10: 0= no impact 10= severe impact
5	**Risk score**	Calculated as hazard rating multiplied by vulnerability rating	Indicator of the risk of each type of hazard to the power system after combining hazard severity and the potential/expected impacts	Scale 0-100: 0= No risk 100= Very high risk
6	**Overall risk score**	Calculated as the average of risk scores across all hazards	Indicator of the overall level of risk to the power system, accounting for the different severity of hazards, their potential impacts, and mitigations	Scale 0-100: 0= No risk 100= Very high risk
7	**Resilience indicator**	Calculated as 100 minus the overall risk score	Indicator of the power system's overall resilience to climate events and natural disasters	Scale 0-100: 0= No resilience/very low resilience (worst) 100= Very high resilience (best)

Overview of outputs

Hazards				Risk without mitigation		Risk with mitigation		
#	Extreme natural event	Hazard	Hazard rating	Impact rating	Unmitigated risk score	Mitigation rating	Vulnerability rating	Risk score
1	Rising temperatures	Higher ambient temperatures	3	5	14	12%	4	13
2		Less rainfall	5	6	29	50%	3	14
3		Long periods with no rain	4	6	23	50%	3	11
4	Tropical cyclones	Strong winds	5	7	35	50%	4	18
5		Heavy rain with long duration	6	5	30	50%	3	15
6		Intense short duration rainfall	7	5	35	50%	3	18
7	Storms	High winds	8	5	40	50%	3	20
8		Lightning	8	7	56	50%	4	28
9		Storm surge	4	5	20	50%	3	10
#		Landslides	6	7	42	50%	4	21
#	Sea level rise	Coastal inundation	10	5	50	50%	3	25
#	Tsunami	Flooding	4	6	22	50%	3	11
#		Costal destruction	5	6	30	50%	3	15
#	Earthquakes	Seismic shocks	2	8	16	50%	4	8
#	Volcanoes	Overland lava flow	1	8	8	50%	4	4
		Overall risk score (average)			30			15
		Resilience indicator (100 minus overall risk score)			70			85





Cover | Guidance | Example | Hazards | Impacts & Mitigation | Summary

Session 3 –
Resilience Assessment Tool Practical Exercises

Use the tool to assess the resilience of your system

- Work together in small groups (2 or 3), ideally with people from the same country or systems that share similar characteristics
- Use the tool to assess the resilience of your system
- No need to be too precise – do a ‘quick and dirty’ assessment now and you can come back to it later
- Ask Alex or Richard if you want to add hazards or exposed assets and we will show you how
- Be prepared to briefly present your results to the wider group
  - This is NOT a competition to see which system is more resilient. The relative ratings are not very meaningful, because we are doing it in such a hurry and because it involves a lot of judgement. What is useful is thinking about hazards, impacts, and mitigation systematically.
  - You may have key lessons or insights you want to share with the group. Eg, a vulnerability or mitigation you had not previously considered. Or maybe other utilities have already come up with good ways to mitigate vulnerabilities that you can learn from.

Session 4 –
Introduction to Resilience Viability Tool

Tools to support Pacific utilities in improving their resilience

Identify risks of extreme natural events (climate and disaster related)
- Understand the hazards exposed to and the potential impacts

Identify resilience measures that could be implemented
- How can these potential impacts be (partially) mitigated

Resilience Assessment Tool
Initial 'high-level' assessment to identify climate-related risks and potential resilience measures

Screen and select resilience measures
- Determine the technical and economic viability of identified resilience measures

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Monitor and evaluate measures
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Put in place financial protection
- Eg. Self-insurance programmes

The Resilience Viability Tool can be used to decide whether an investment that improves the climate resilience of a power system is justified

The tool compares the costs and benefits of the resilience investment under two scenarios:

Without climate resilience

- The business as usual investment
- E.g. replacing an aged generator housing in 5 years

With climate resilience

- Spending more to climate proof the asset
- E.g. replacing the generator housing now and upgrading specifications to make it flood proof

If the extra benefits from the climate resilient investment outweigh the additional costs, then the investment is viable. The tricky part is quantifying those extra benefits…

Investments should be evaluated from the perspective of society as a whole, rather than on financials alone

An investment that improves the climate resilience of a power system is viable if its benefits outweigh its costs. Those benefits and costs should be evaluated in economic terms, i.e. from the perspective of society as whole, rather than be evaluated in purely financial terms (from the perspective of the utility).

Financial analysis

- Evaluates costs and benefits from the perspective of the entity making the investment (i.e., the **electricity utility**) and asks **whether the financial revenues** accruing from the investment over its life are likely to **outweigh the upfront costs** of making the investment.

Economic analysis

- Evaluates costs and benefits from the perspective of **society** as a whole (i.e. the economy) and considers a range of benefits beyond financial transactions. For example, if an investment results in fewer electricity outages, the benefit to society is typically larger than increased tariff revenues for the utility.
- Economic analysis also requires quantifying costs and benefits based on 'shadow prices', which reflect the underlying economic value, rather than market prices. This means excluding transfers from one group within society e.g. taxes

The tool focuses on the most likely costs and benefits related to climate resilient investments

Types of costs

- **Incremental investment costs.** The upfront cost of making an investment, i.e. how much extra needs to be spent upfront to make the investment more climate resilient?
- **Incremental operating costs.** The annual cost of operating and maintaining the assets, i.e. how much extra is it going to cost to operate and maintain the more climate resilient asset?

Types of benefits

- **Avoided costs of replacement/repair.** Each time there is a climatic or extreme weather event, how much will it cost to replace or repair assets? Climate resilient investments are likely to be less adversely affected, and therefore will require less replacement/repair.
- **Avoided cost of outages**. Each time there is a climatic or extreme weather event, how many customers are likely to face a power outage? Climate resilient investments are likely to be less adversely affected, and therefore will lead to fewer outages. The cost of outages should be valued at the 'Value of Lost Load' (VOLL) rather than the electricity tariff.
- **Environmental benefits**. In some cases, the 'without climate resilience' scenario may lead to higher emissions, for example due to increased standby diesel generation. Valuing carbon emissions can be difficult because there is no global consensus on the cost of future climate change impacts, although one commonly used value is the prevailing price of carbon (or a long-term average) under the EU Emissions Trading System
- **Other difficult to quantify benefits.** These can be included in the analysis as a qualitative 'add-on' to the quantitative analysis. For example, if the investment is borderline viable, then the presence of qualitative benefits could tip the balance

Models to determine economic viability can get very complex. We have endeavored to keep this tool quite easy to use

- It can be tempting to build sophisticated models that give the appearance of being robust, despite the outputs hinging a few key inputs that are inherently uncertain. This is especially true when evaluating the impact of future climatic events, for which there is a wide range of possible future outcomes.
- The Resilience Viability Tool has two key features which keep it easy to use:

Quantifies the impacts of extreme events into just two categories – Minor and Major

- Rather than inputting the frequency and impacts of a complex array of different climatic events (flooding, cyclones, earthquakes, tsunamis, etc).
- What constitutes a major event is specific to the type of investment being evaluated – for example a major event, in the context of whether to elevate a generator, would be events that cause surface flooding.

Assumes that the benefits are the same in every year of the investment's life

- This means that the evaluation of an investment occurs in three columns – without climate resilience, with climate resilience, and difference – rather than entire worksheets.
- We avoid adding a spurious level of detail and do not estimate incremental costs and benefits that change over time – for example the frequency of events will likely increase over the life of an investment, but modelling this would only layer uncertain assumptions on top of other uncertain assumptions and is unlikely to make a decisive impact on the result

The tool accounts for the differences in the timing of investments (with and without climate resilience)

Examples of the importance of factoring in timing differences:

- Constructing distribution boxes out of stainless steel rather than zinc plated steel may not make a significant difference to ability of the boxes to withstand a single weather event. But it will protect them from chronic effects of climate change – i.e. rusting from exposure to semi-frequent weather events. This difference should be reflected in a longer asset life for the climate resilient asset.
- To evaluate whether to underground MV lines, it may not be fair to only assess the cost of undergrounding. The existing overhead lines may already be old and need replacing soon anyway, in which case the fair comparison would be the cost of new underground lines today versus the cost of new overhead lines in the future (e.g. 10 years' time)

The model accounts for timing differences in two ways ways:

- In its conversion of upfront investment costs to equivalent annual costs (an asset with a longer life will have a lower annual cost)
- By decreasing the upfront investment costs of any investments that do not need to be undertaken right now. For example, a substation upgrade in 5 years time will be cheaper, in today's terms, than the same upgrade made this year

An investment is viable if the benefits outweigh the costs

Because the tool converts all costs and benefits into constant annual amounts, our assessment of viability is very simple: **Do the annual incremental benefits outweigh the annual incremental costs?**

The tool also calculates two additional indicators, which are commonly used when assessing economic viability:

- **Net present value (NPV) of benefits less costs.** This is in effect the sum of all benefits less the sum of costs, with future benefits and costs discounted at the social discount rate to reflect the time value of money. The NPV rather than the arithmetic sum should be used because it correctly reflects the fact that 'a dollar spent today is more expensive than a dollar spent in the future', or put differently, 'consumers prefer to consume today rather than in the future'. An investment is viable if the NPV is greater than zero.
- **Internal rate of return (IRR).** This is a different indicator than NPV, but it is interrelated. It represents the discount rate at which the NPV of benefits less costs equals zero. An investment is viable if the IRR is greater than the social discount rate. A 9% social discount rate is the Asian Development Bank's default social discount rate.

Session 5 –
Practical exercise with Resilience Viability Tool

Use the tool to test the viability of an example or hypothetical investment

- Work together in small groups
- Discuss among yourselves some investments that your utilities has been considering which will improve system resilience
- Pick one of those investments (if you cannot think of an actual investment, come up with a hypothetical one)
- Input it into the tool and see if it is viable versus the ‘without climate resilience’ (ie. business as usual) investment
- One you have a result, change some of the key inputs to test how sensitive the result is
- Be prepared to briefly present your results to the wider group

Alex Schmid
alex.schmid@eca-uk.com

Richard Bramley
richard.bramley@eca-uk.com