Synthesis of storylines through common policy directions: a causal network approach

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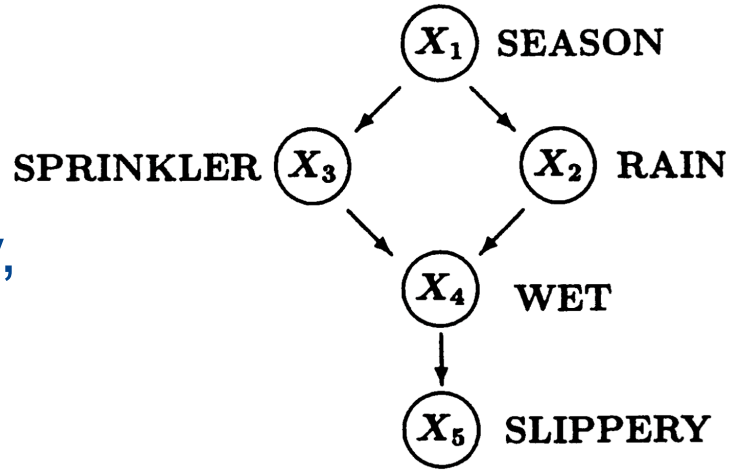
What are causal networks?

- Directed Acyclic Graphs (DAGs) with probabilistic dependencies represented by the graph structure.

- Constructed to show causal relationships graphically, and answer inference queries,
  e.g. what happens with interventions.

  ⇒ Can embed and explore climate storylines by matching nodes corresponding to storyline elements (e.g. a climate event) (Shepherd 2019)



(from Pearl 2009)

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Why causal networks?

- Incorporating uncertainties as probabilities assigned to the nodes; Notably, user value judgements can be incorporated (Kunimitsu et al 2023).

- Allows the elicitation of priorities, leading to user-tailored policy recommendations, and can be used as a decision support tool.

- Can also be used as an interface for exploring the storyline, including sensitivity analysis and investigation of possible policy options

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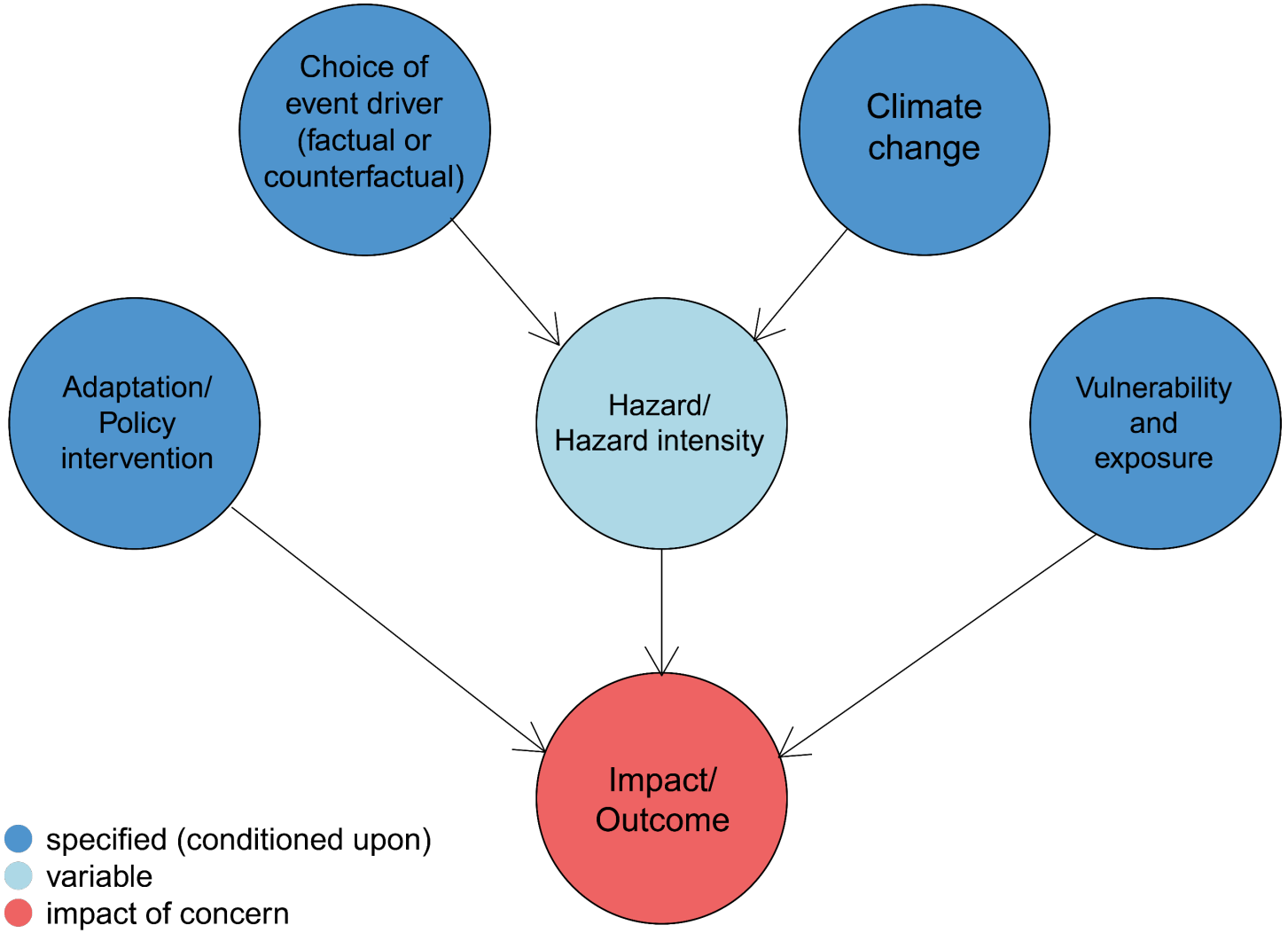
Prototype causal network for storylines



- Storyline elements can be categorized into certain types of nodes
- These include
  - Event (e.g. cyclone)
  - Climate change
  - Exposure, vulnerability, policy, …
  - Outcome (e.g. economic impact)

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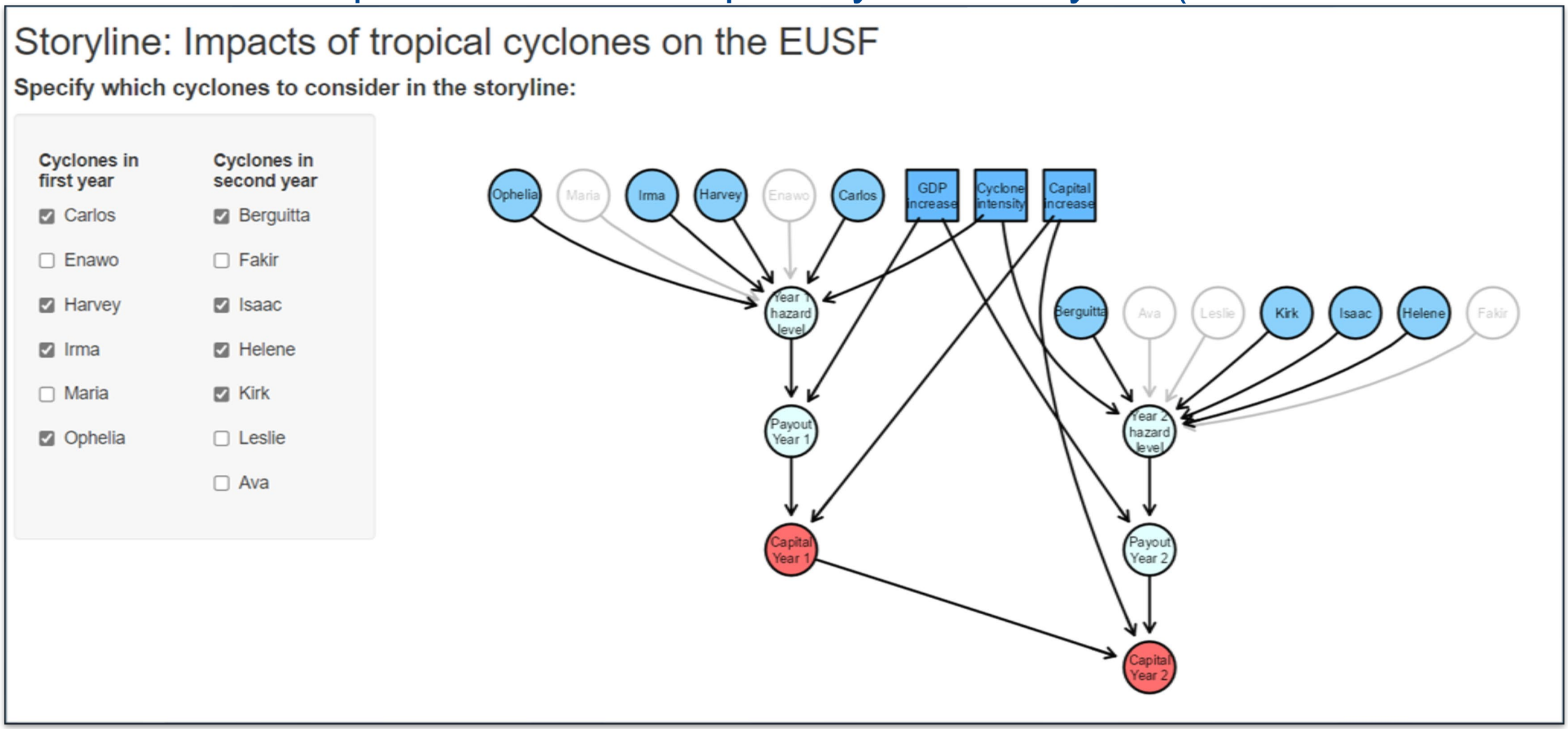
Example: storyline of tropical cyclone impacts

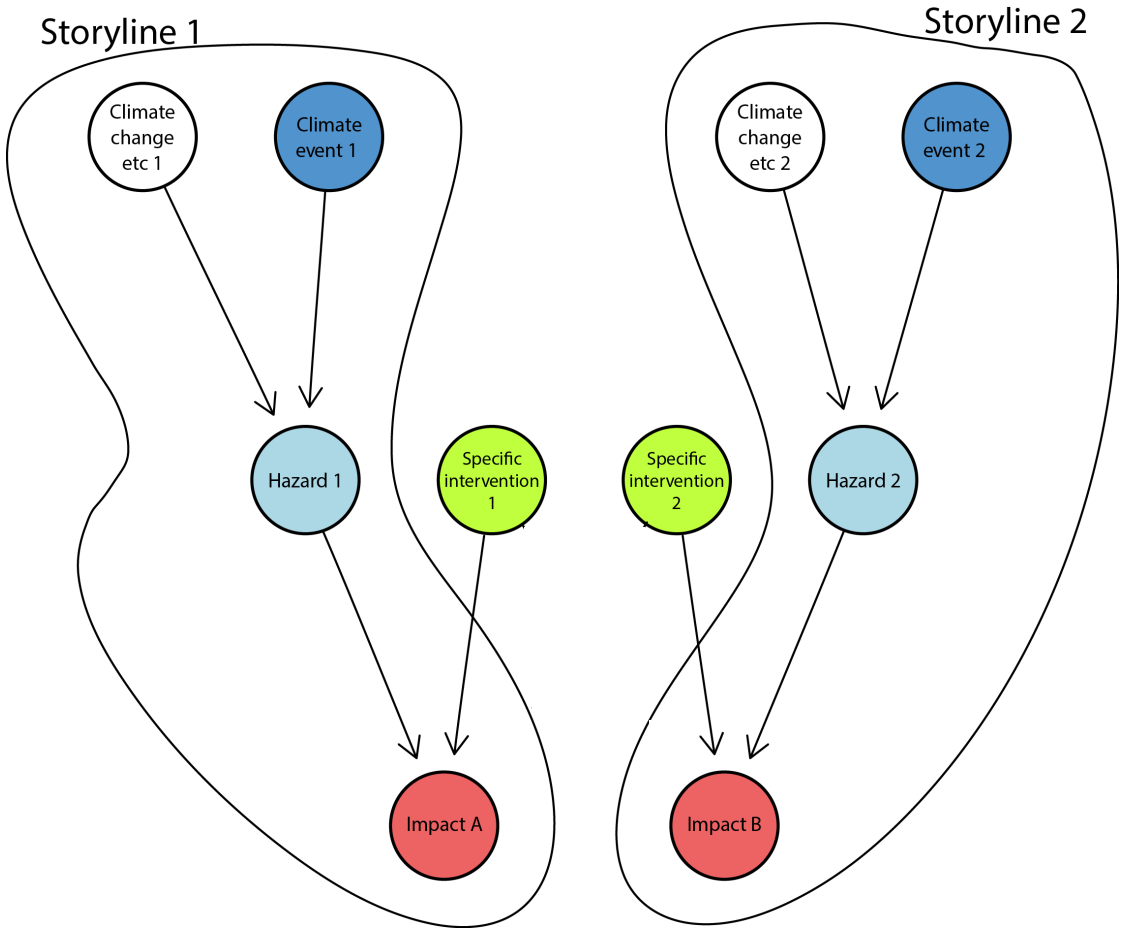
- Causal network implementation of tropical cyclone storyline (Kunimitsu et al. 2023)



Combining storylines – Why?

- Exploring systemic risk – unforeseen connections: simultaneous events, multisector impacts, etc.

- Even without such connections, we want storylines to be policy relevant
- Storylines are context specific, but consistent storyline messages from multiple storylines would have broader implications on decision making



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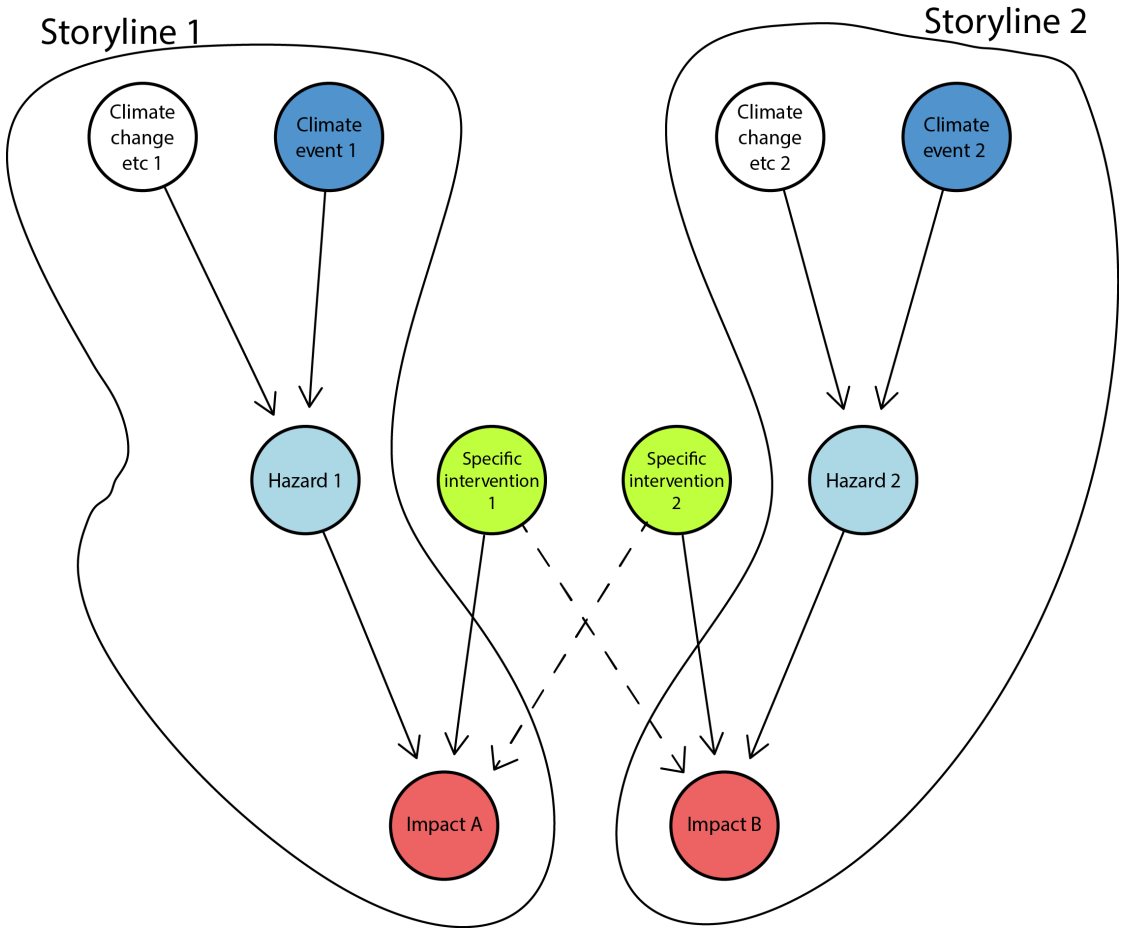

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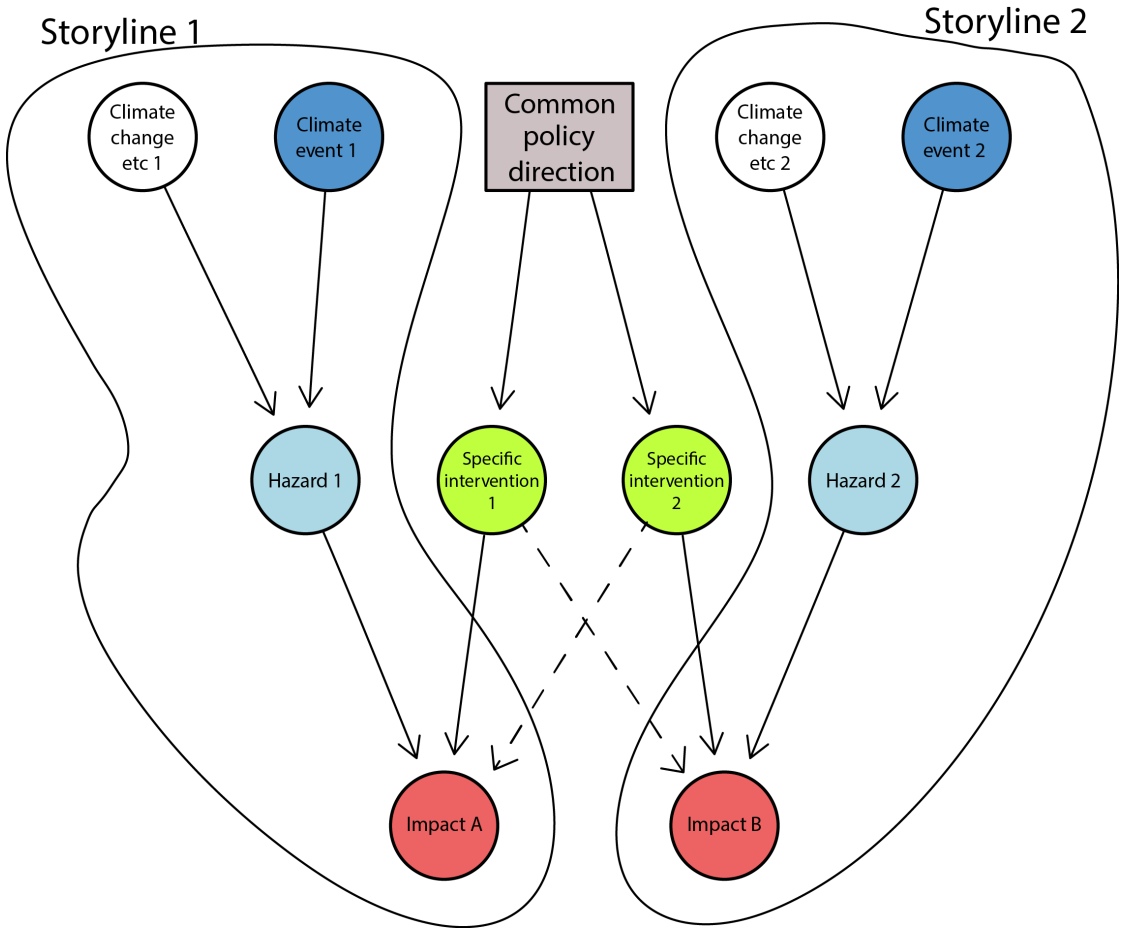
Combining storylines with common policy directions

- We align the policy interventions using a **common policy direction** node
  - General enough to accommodate multiple storylines
  - Specific measures conditional on the node

- Ensures coherence between the storylines
- Outcomes of the storyline can be interpreted under the same assumptions, and consistent policy implications would become meaningful

- Resembles shared climate policy assumptions (SPAs) in the SSP-RCP scenarios framework, but more context specific



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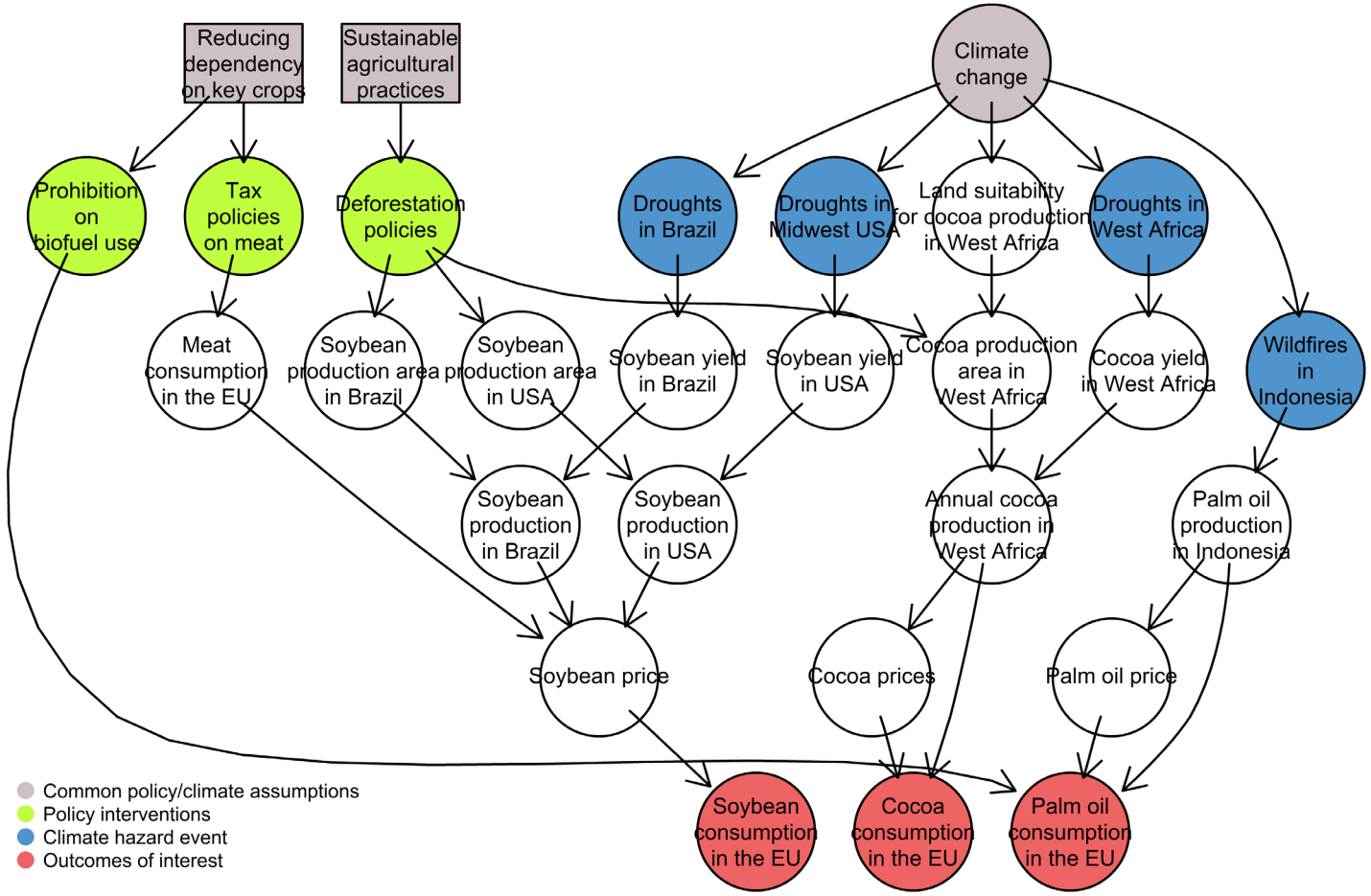
Example: storylines of climate change impacts on the agriculture sector in Europe

- Three agricultural storylines: Soy, Palm oil, Cacao
  (RECEIPT WP3, see e.g. Goulart et al. 2023)

- Common policy direction:
  1. Promoting sustainable agricultural practices
  2. Reducing internal dependency on key crops

- Sustainability policies (e.g. restricting deforestation) lead to higher prices, already expected from climate change
- Note the policy message is not necessarily sustainability policies should not be taken – rather adaptation measures should be scaled up



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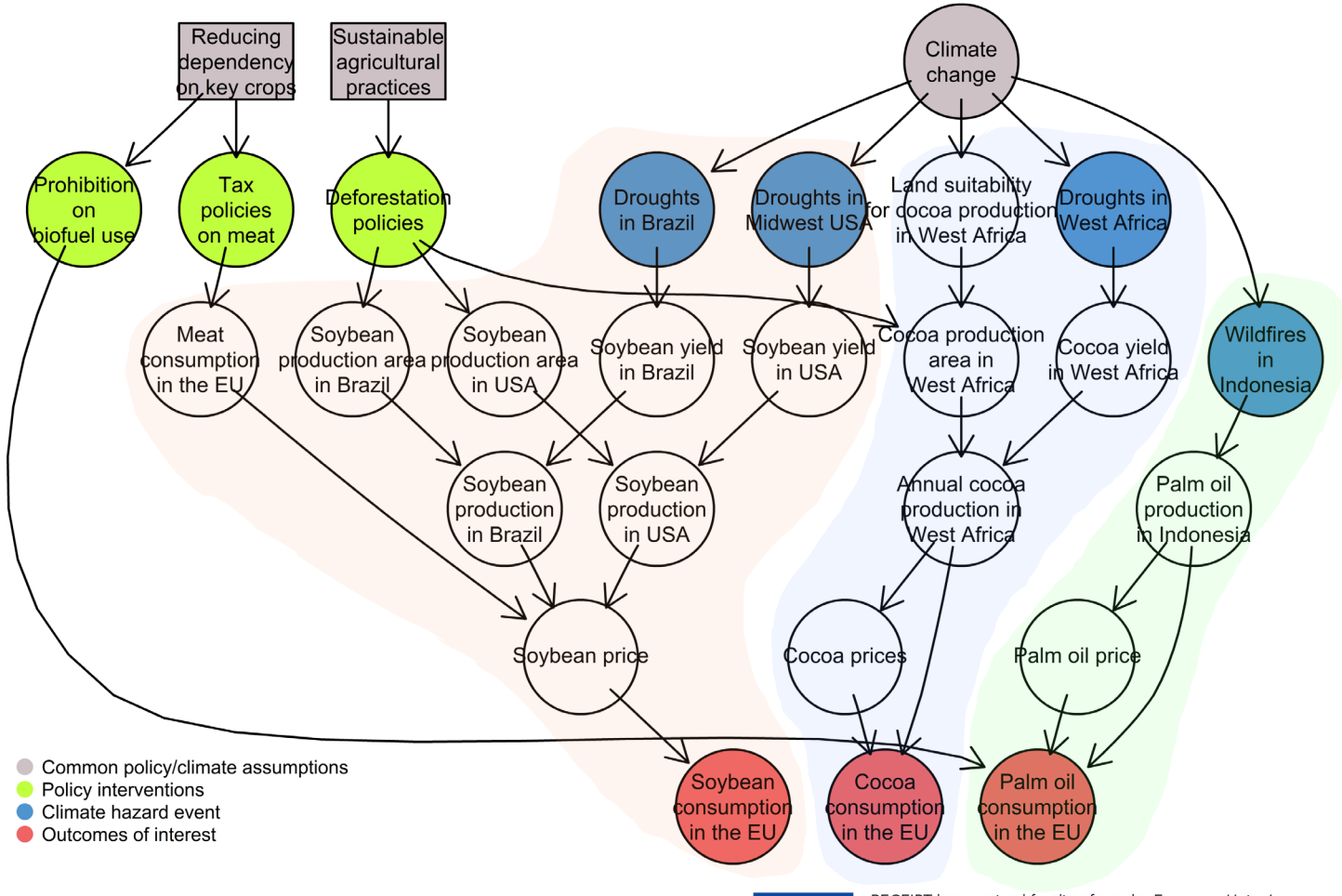

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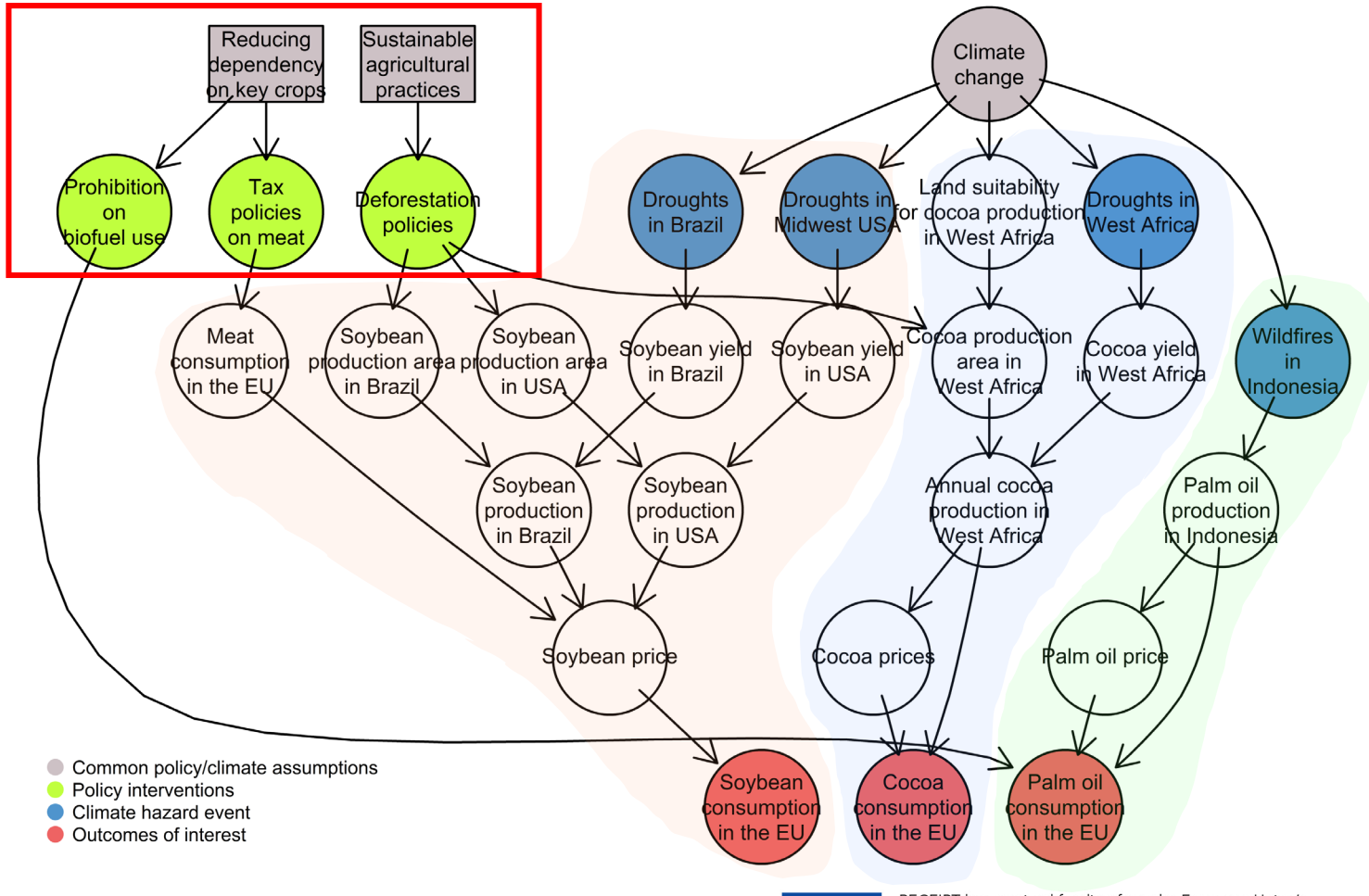

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Summary

- Storylines combined through **common policy directions** using the causal network framework

- Consistency and coherent messaging of storylines, policy implications covering multiple sectors

- Unified assumption framework like SSP-RCP-SPA, but more context dependent

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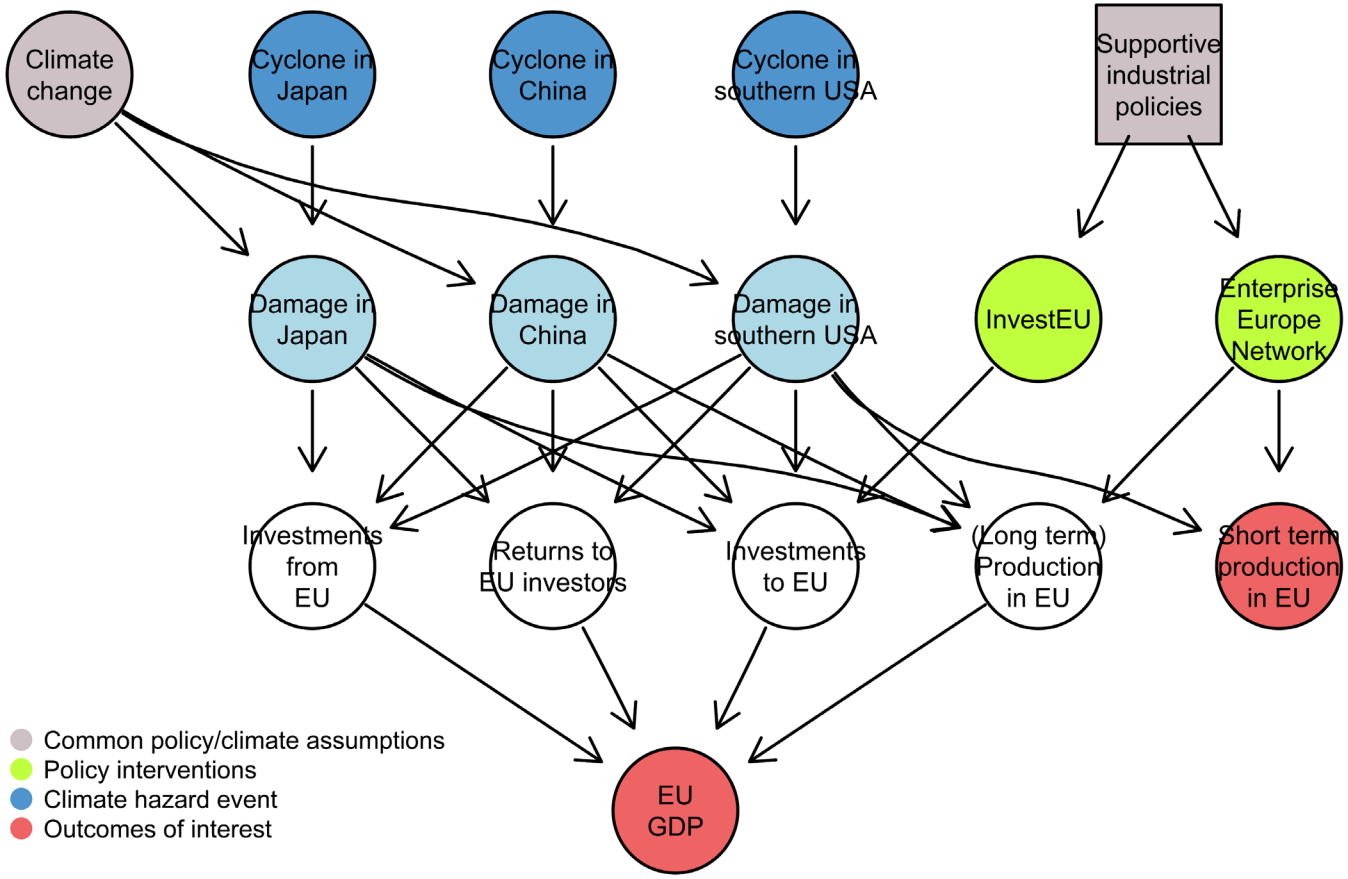
Example: Tropical cyclone impacts on trade and financial investment



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Impacts in agricultural storylines

Impact of event with no policy intervention				
Impact	Direction	2.5 °C (~RCP2.6 in 2050)	3 °C (~RCP8.5 in 2050)	4 °C (~RCP8.5 in 2100)
Soybean consumption	↘	-3 %	-12 %	-
Soybean prices	↗	+16 %	+28 %	
Cocoa consumption	↘	-11 %	-	-20 %
Palm oil consumption	↘	-0.2 % (2 °C)	-0.3 %	-
Additional impact of event under sustainable policies				
Impact	Direction (compared with no policy)	2.5 °C	3 °C	4 °C
Soybean prices (Deforestation ban)	↗	+4 %	+0.9%	-
Cocoa consumption (Deforestation ban)	↘	-18 %	-	-26 %
Additional impact of event under dependency reduction				
Impact	Direction (compared with no policy)	2.5 °C	3 °C	4 °C
Soybean prices (Halve meat consumption[4])	↘	-15 %	-7%	-
Palm oil consumption (Ban on biofuel use)	↘	(Possibly halve consumption)		

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Impacts in finance/trade storylines

Impact	2 °C	4 °C	Impact direction of storyline	Climate impact	Expected policy impact direction if implemented
Short-run Global production (WP6)	+$8B gain (1 year)	+ $6B gain (1 year)	↗	↘	↗ (Support for larger investments from Europe)
(Excluding US)	(+$8B)	(+$11 B)	(↗)	(↗)	
Medium-run European GDP (WP4)	-0.2 % (~10 years)	-0.3 % (~10 years)	↘	↘	↗ (Better investment environment in Europe)
Long-run European GDP (WP4)	-0.05 % (~40 years)	-0.1 % (~40 years)	↘	↘	↗ (Better investment environments in Europe)

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The RECEIPT project

Receipt

REmote **C**limate **E**ffects and their **I**mpact on European sustainability, **P**olicy and **T**rade

- How will remote climate events outside Europe impact Europe?
  - Answers this through the use of multiple **Climate Storylines**

- Sectors of focus:

- Output: Synthesis of risks and connecting to policy recommendations
  - We integrate the sectoral storylines using **Bayesian Networks**

Climate Storylines for decision making

What is a storyline?

- A physically self-consistent unfolding of past events, or of plausible future events or pathways (Shepherd et al. 2018)
  - Typically, a narrative of a historical event (past floods, droughts) under future climate and socioeconomic conditions, "what-if-things-had-been-different"

  ⇒ Leads to greater engagement and policy relevance (Sillmann 2021)

- Complements a "risk-based approach"
  - Analysis is conducted conditional on event and/or condition
  - Not necessarily assigning probabilities to the events

(Event) Storylines for decision making

- Typically, a narrative of a historical event (past floods, droughts) under future climate and socioeconomic conditions, “what-if-things-had-been-different”

  ⇒ Leads to greater engagement and policy relevance (Sillmann 2021)

- Storylines are deterministic
  - No language to quantify relation between storylines with different conditions, or incorporate uncertainty quantitatively
- Policy decisions are made by balancing different priorities

⇒ Use of **(Bayesian) probability** for quantifying uncertainty within the storyline, **causal networks** as a tool for embedding the storylines

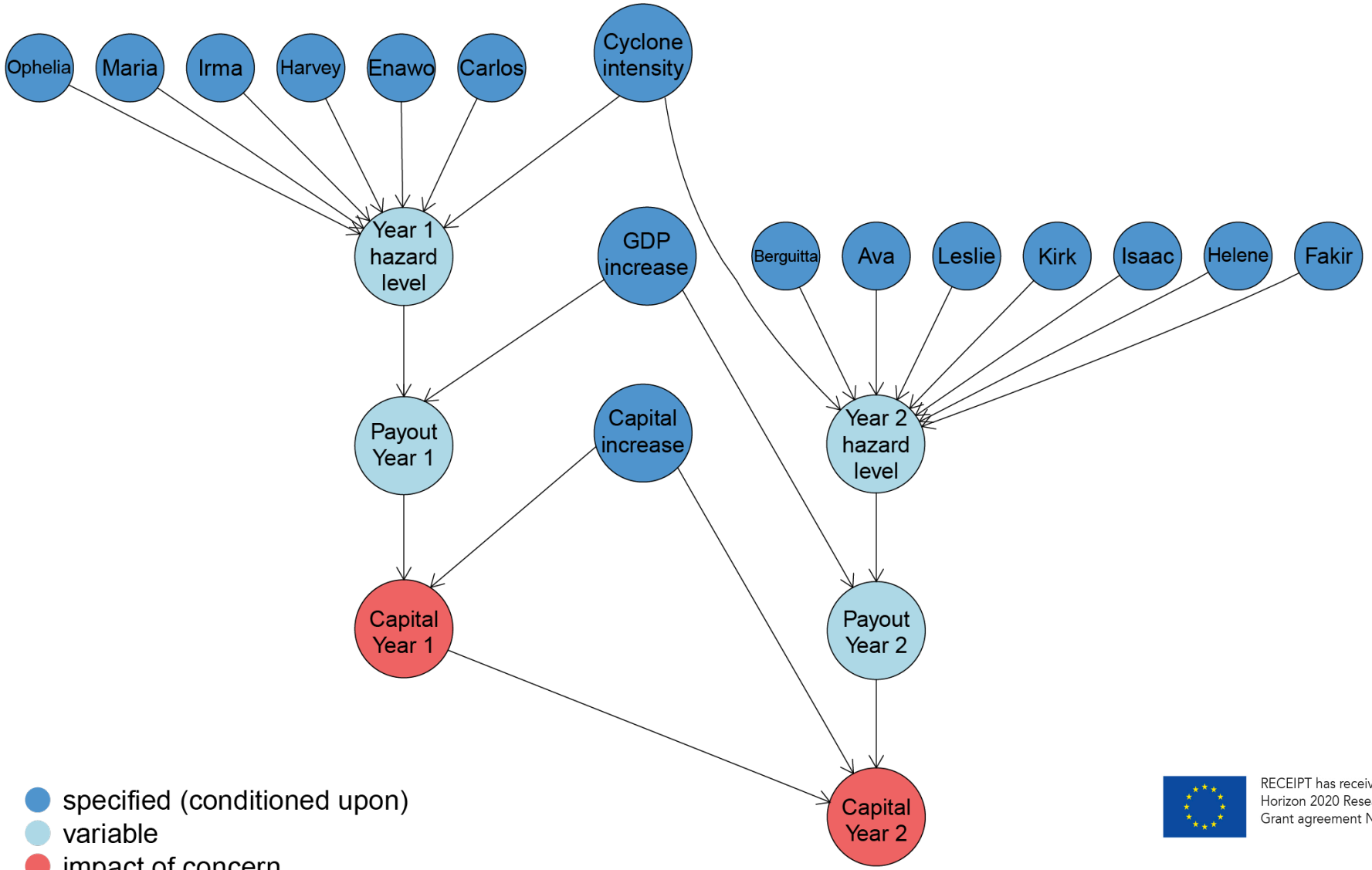
How is the storyline chosen?

- Can estimate using damage caused in synthetic simulations
  - STORM (Bloemendaal et al 2020) -> 1 cyclone a year on average
  - Assuming linear relationship between frequency and wind speed
  - Note the statistical assumptions are difficult to justify for each storyline (specific set of cyclones)

- Base on historical realizations = 2 cyclones in the 2 years
  - Consistent with above estimates

- Ultimately a matter of choice
  - Stakeholder engagement is crucial

Causal network for the EUSF storyline



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- specified (conditioned upon)
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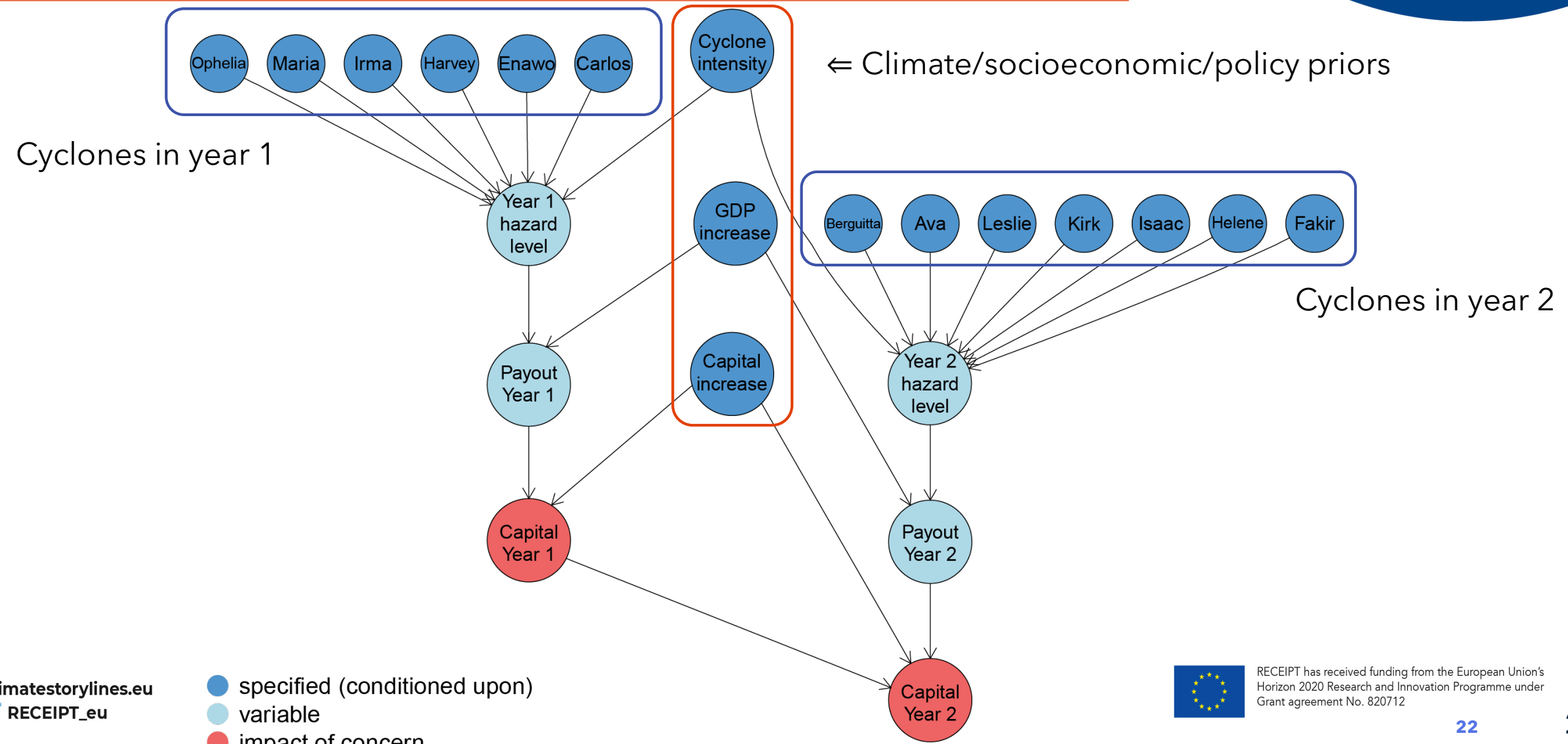

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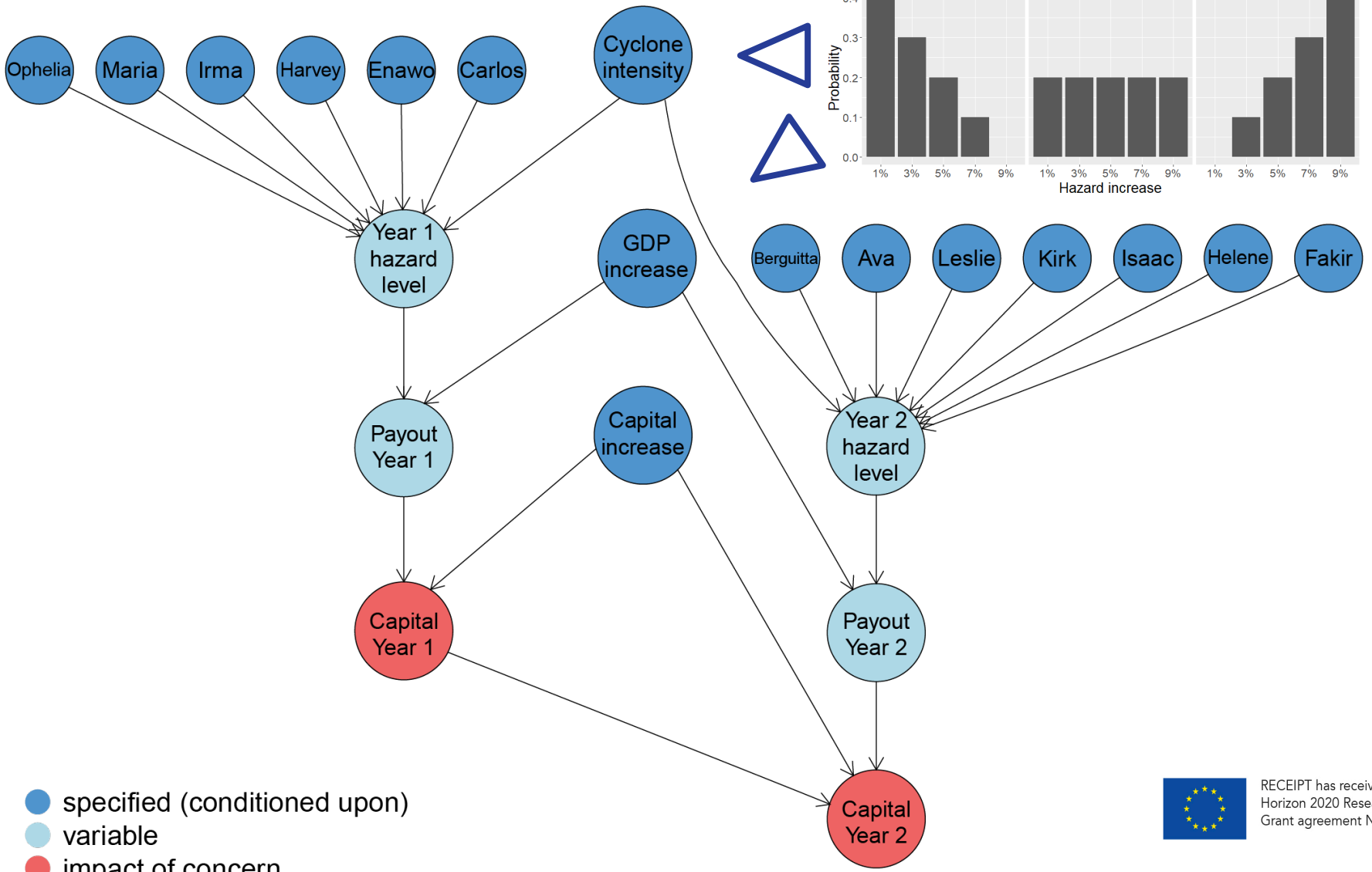
Probabilities as user value judgements



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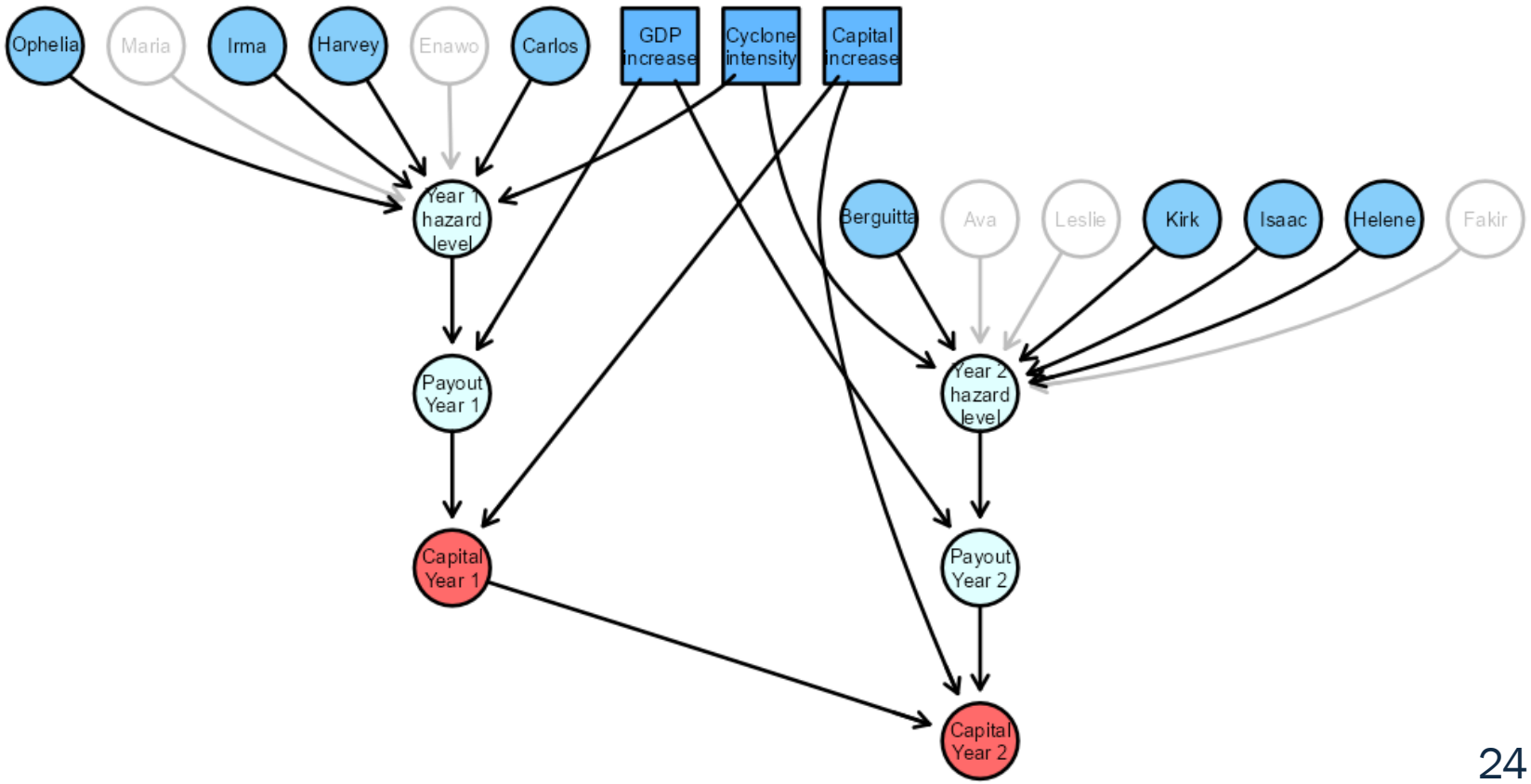
User interface

Storyline: Impacts of tropical cyclones on the EUSF

Specify which cyclones to consider in the storyline:

Cyclones in first year	Cyclones in second year
☑ Carlos	☑ Berguitta
☐ Enawo	☐ Fakir
☑ Harvey	☑ Isaac
☑ Irma	☑ Helene
☐ Maria	☑ Kirk
☑ Ophelia	☐ Leslie
	☐ Ava



A user can input climate and socioeconomic expectations of the future (= user values)

Outcomes of specific policy options | Outcomes of specific policy options (specify prior distributions) | What policy to take to achive positive capital value

Set probability for each increase level in GDP

1% increase	6% increase	11% increase	16% increase	21% increase
0.2	0.2	0.2	0.2	0.2

Set probability for each increase level in hazard intensity

1% increase	3% increase	5% increase	7% increase	9% increase
0.2	0.2	0.2	0.2	0.2

Year under consideration

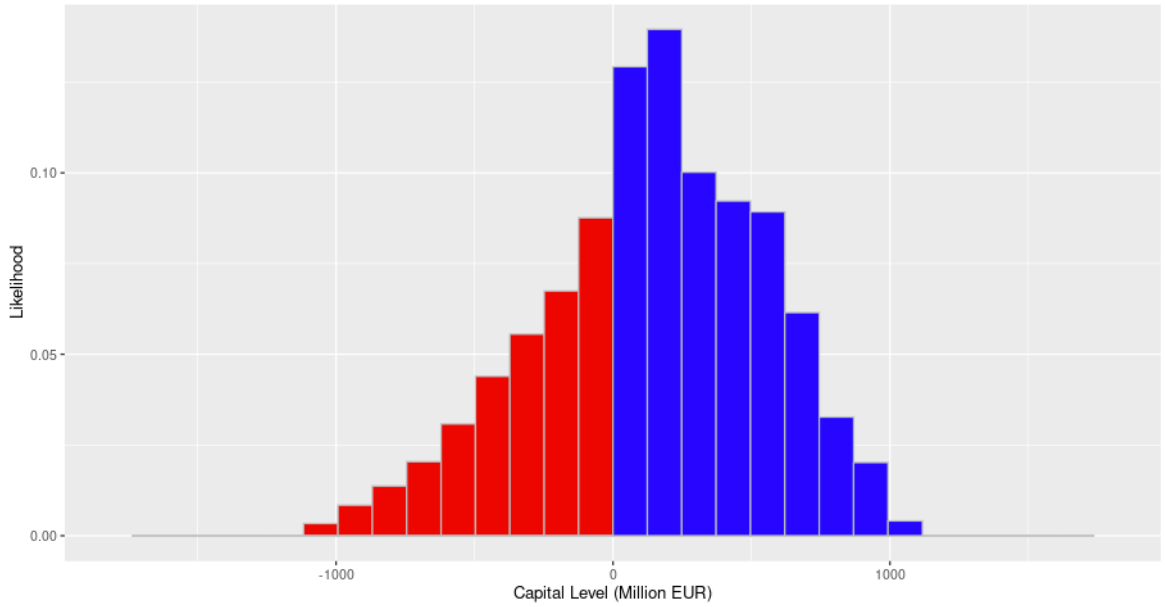
2018

Capital increase in fund (policy)

- ○ 0% increase
- ○ 30% increase
- ◉ 60% increase
- ○ 90% increase
- ○ 120% increase
- ○ 150% increase

Show probability distribution

Will capital levels be positive under the chosen capital increase?



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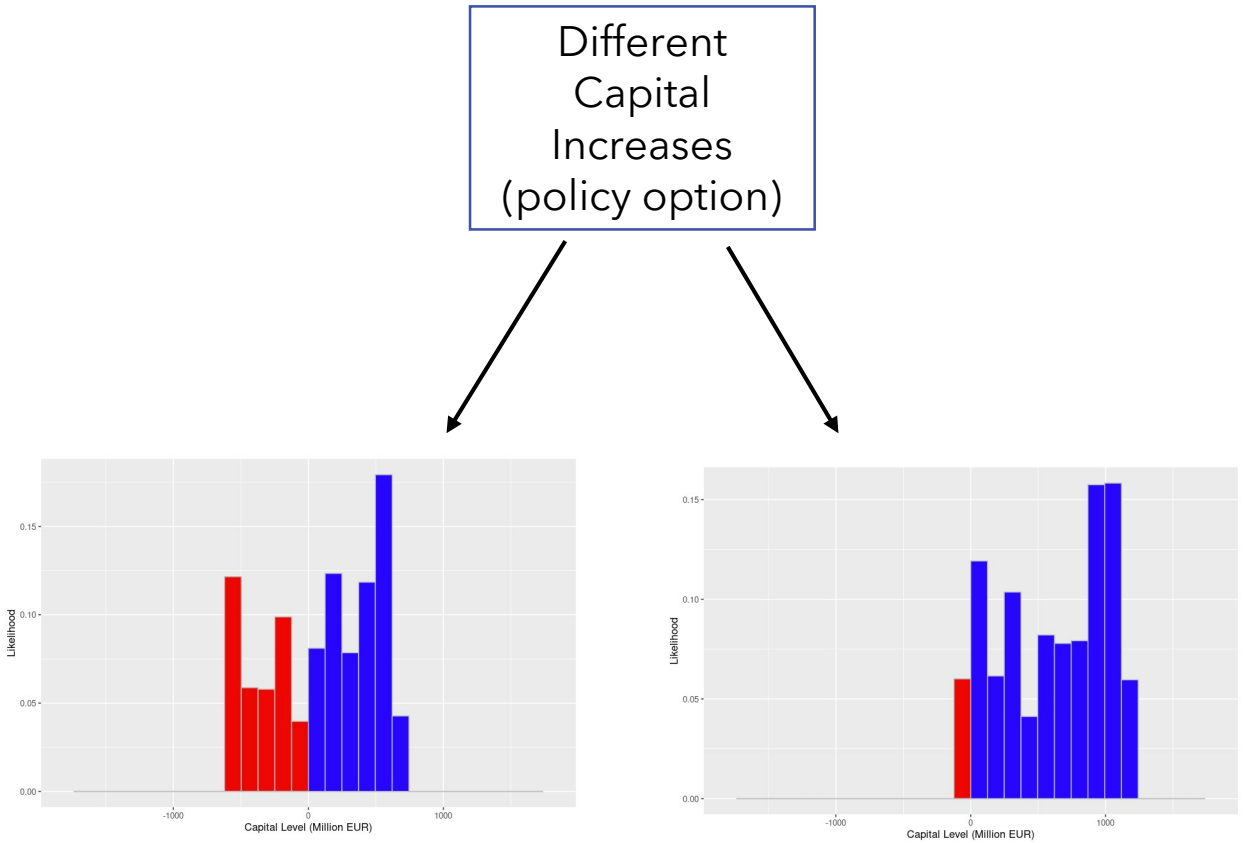
User expectations and risk aversion

- User expectations are incorporated as Bayesian priors to give a probability distribution on the remaining capital
- The user also decides on policy options. A policy recommendation can be created depending on the user's risk aversion (another window to input user values)



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Policy recommendations

- Combine risk-aversion measure with output probability distribution
- If risk neutral, the user will decide to invest an amount that gives positive value 50% of the time
- If risk averse, the user will decide to invest an amount that gives positive outcome 90% of the time
- User-tailored policy recommendations are shown for a given expectation pdf combination and risk-aversion level