Power system planning under a changing climate: recent advances and future directions

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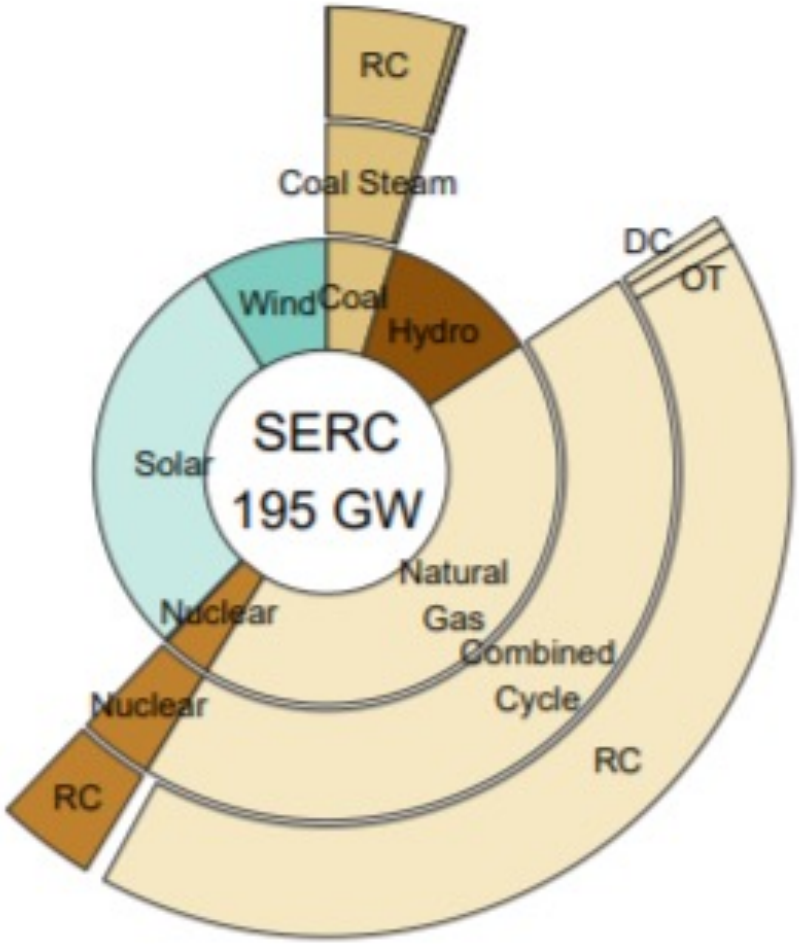
Next Generation Challenges in Energy and Climate Modelling
September 16, 2021



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This talk will answer three questions.

1: How might climate change affect power systems?

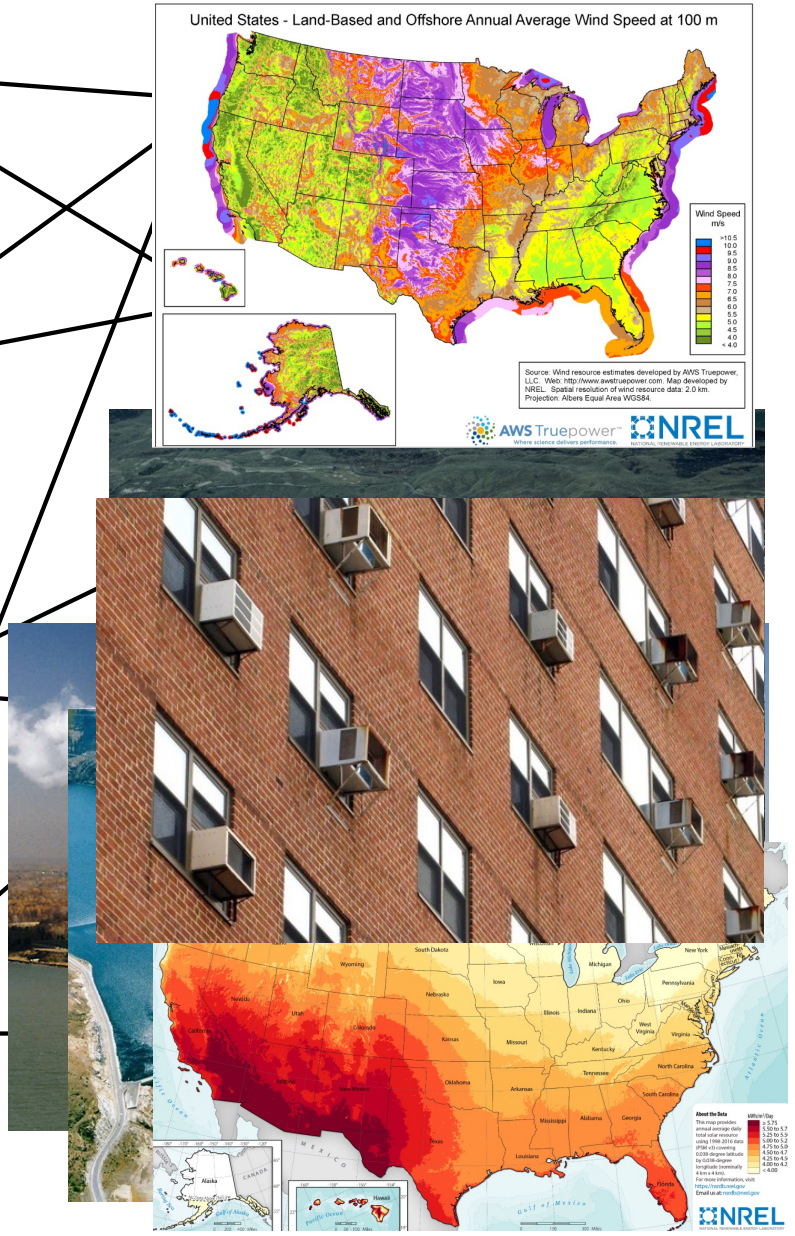
2: How can we incorporate these effects into planning decisions?

3: What new analytical approaches can overcome existing barriers in planning power systems for climate change?

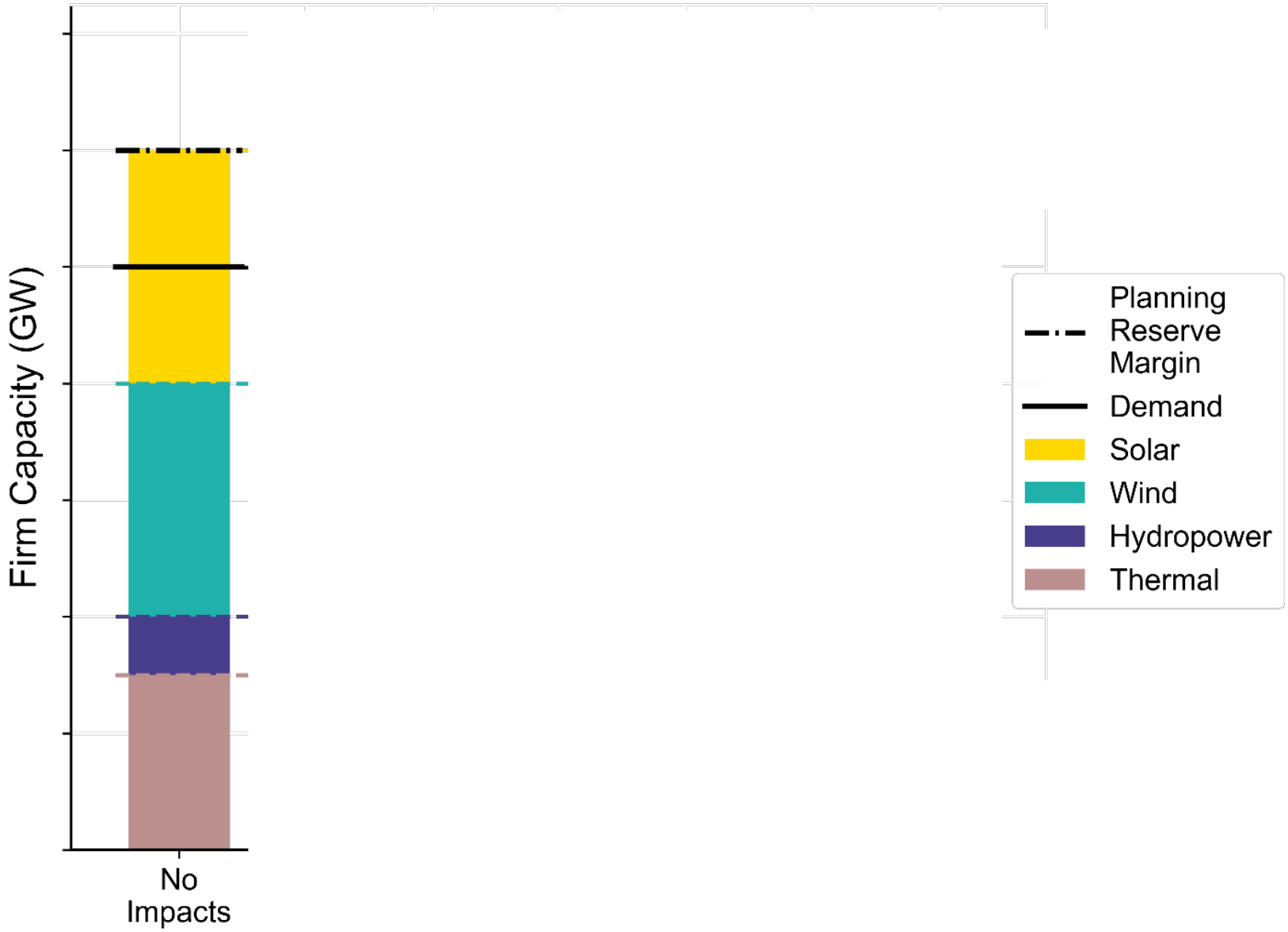
Climate change already is and will continue to impact individual components of the electric power sector.

Climate change

- Increase river temperatures
- Decrease river levels
- Change wind and solar resources
- Increase air temperatures

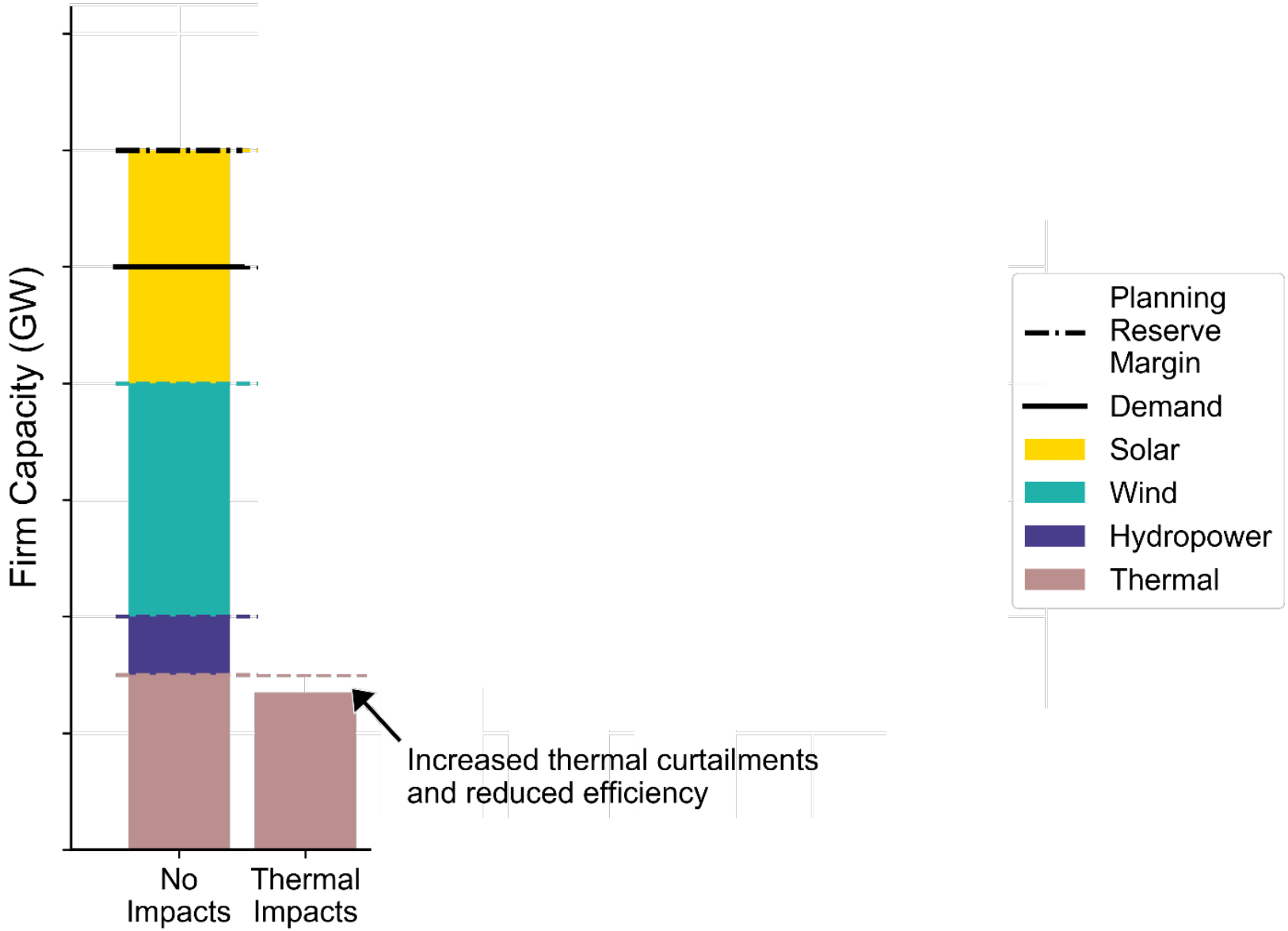


Power system planning aims to ensure sufficient capacity exists to meet demand at all times.



Source: Craig et al., 2018

Climate change will affect system planning through several component-level impacts.



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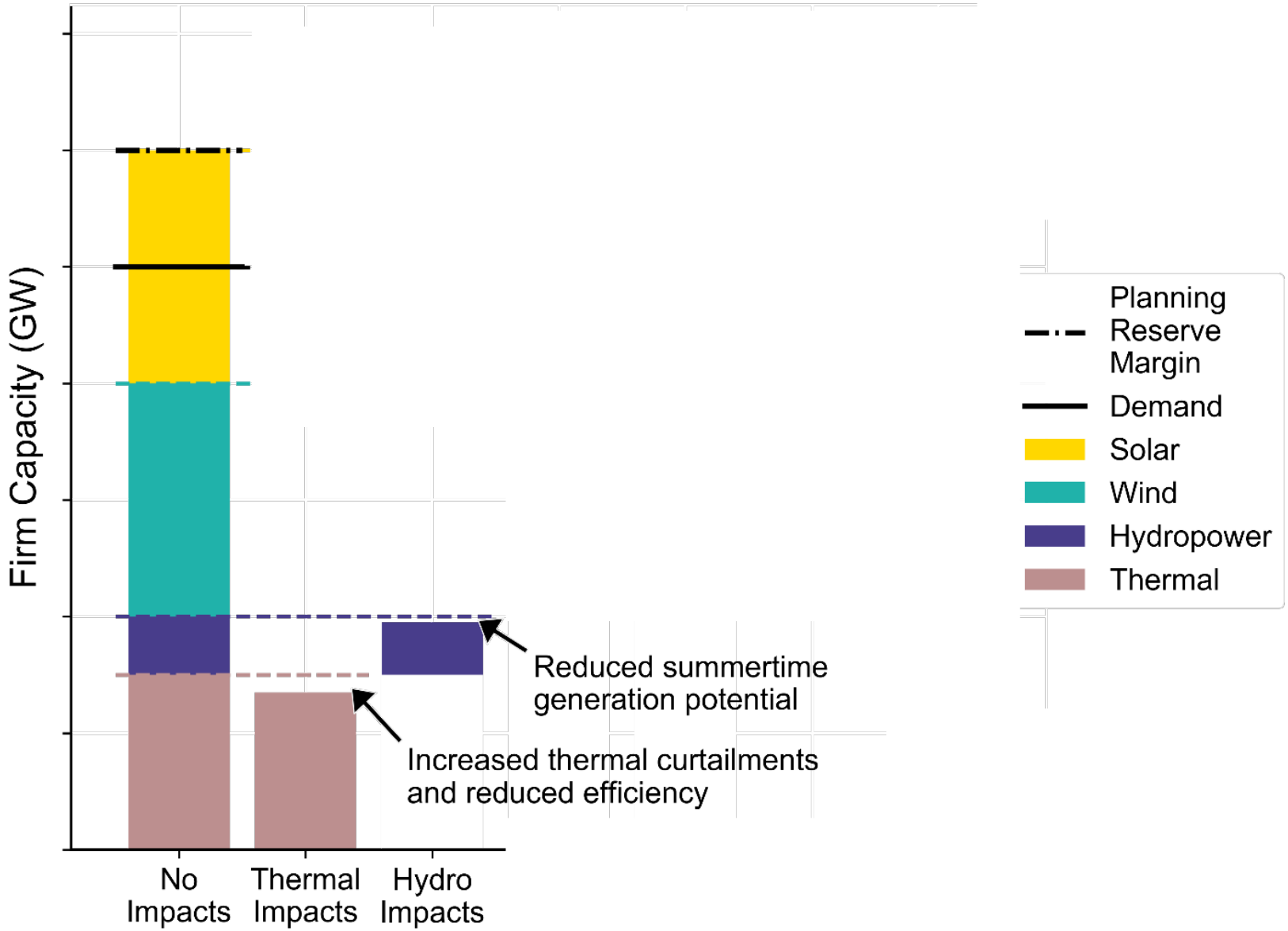

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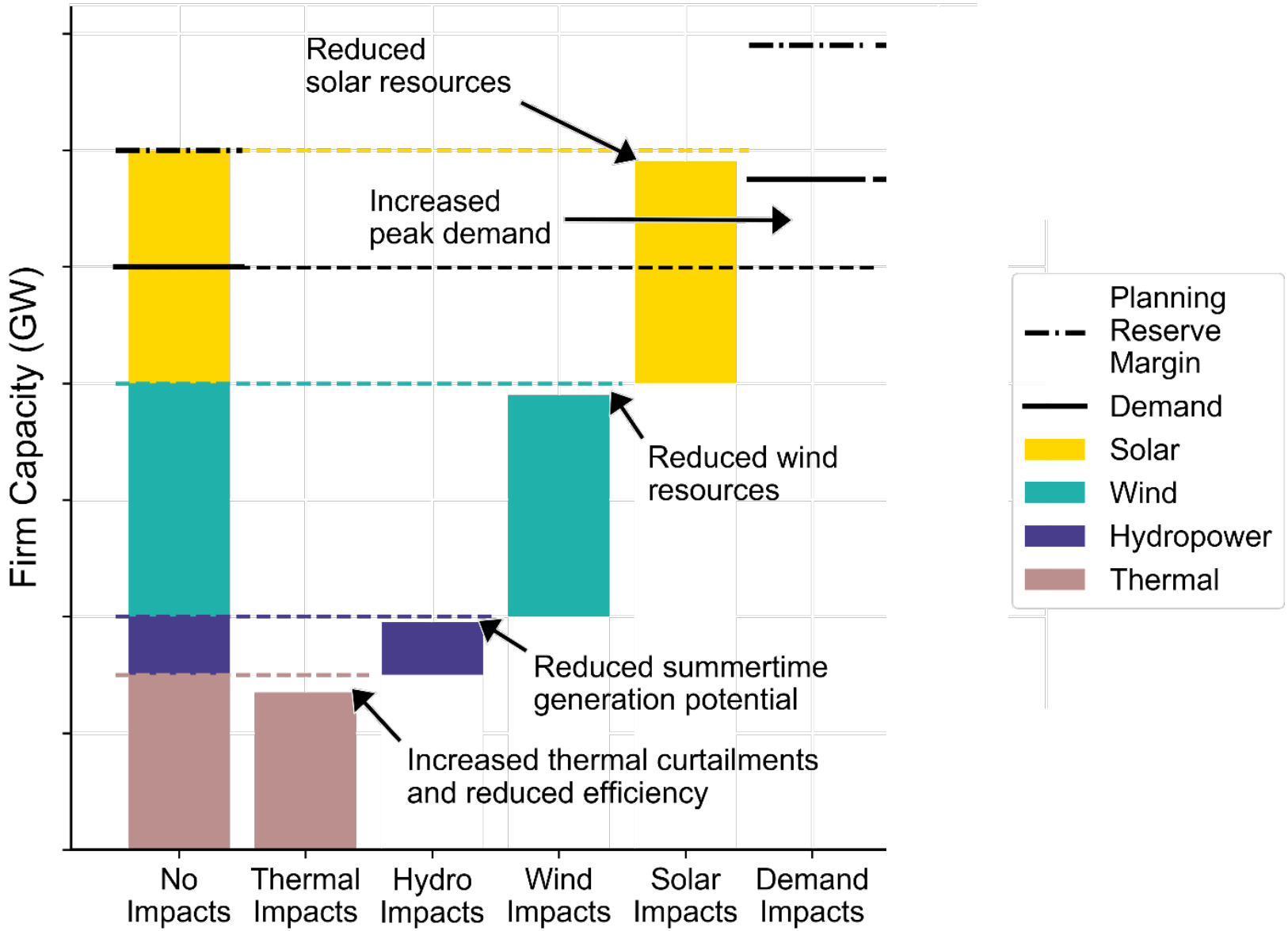

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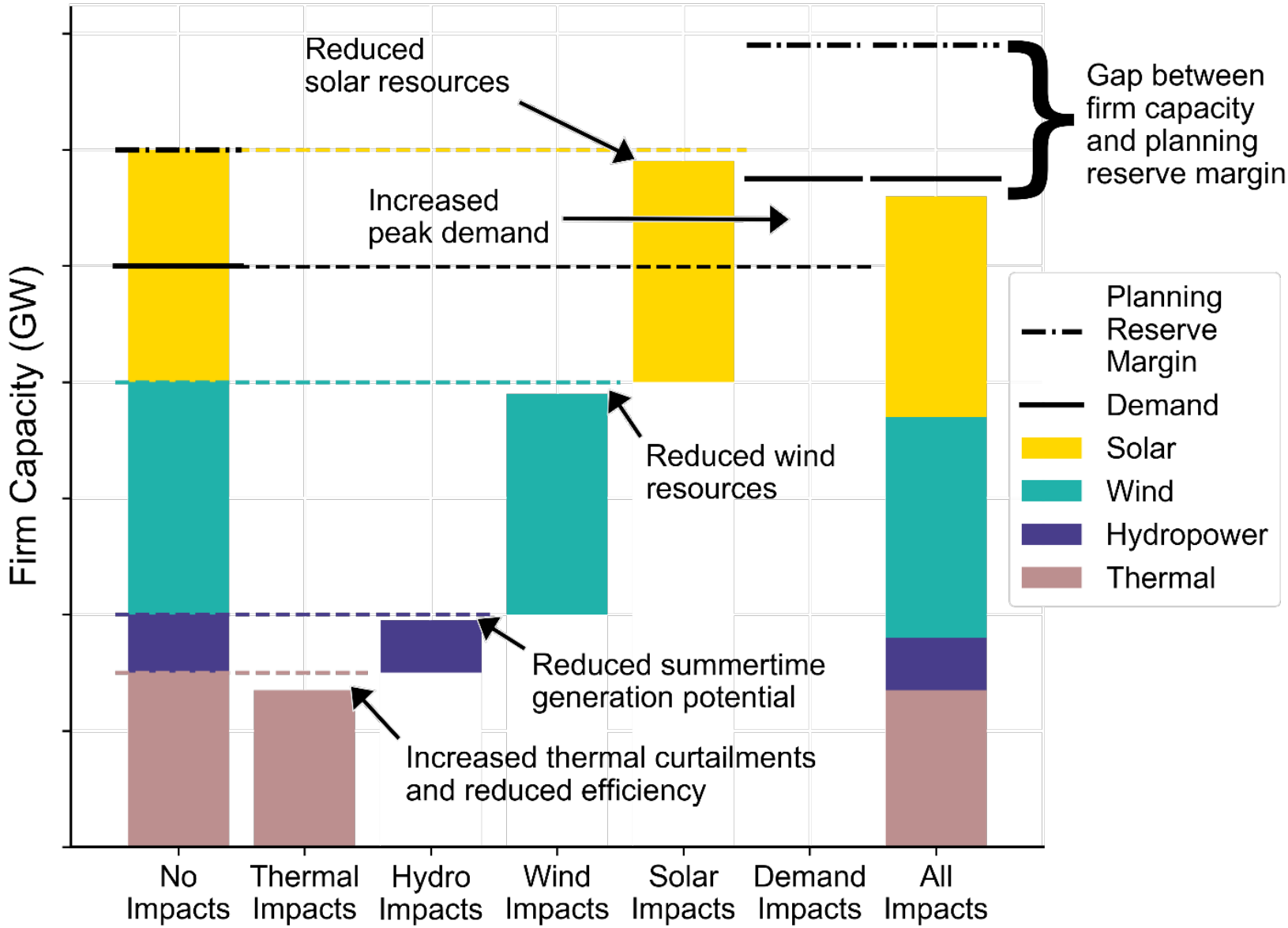
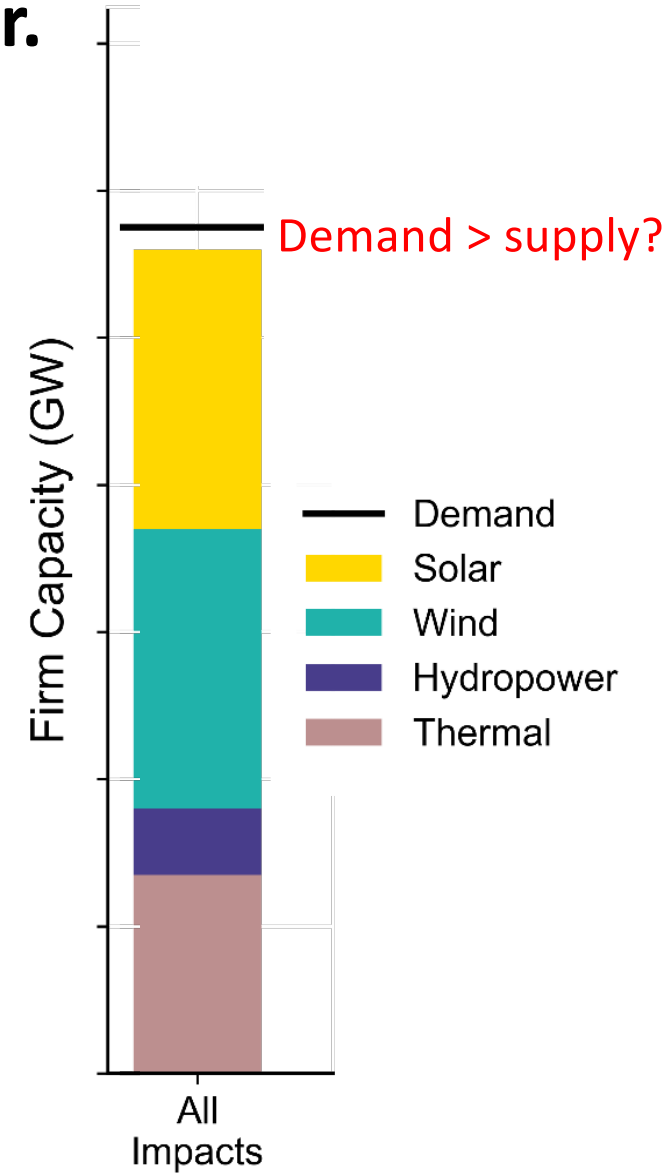
Not planning for climate change might result in under reliable systems.



Source: Craig et al., 2018

System reliability quantifies the probability that supply (capacity) cannot meet demand in *all* hours. If capacity cannot meet demand, outages occur.



Source: Craig et al., 2018

Climate change has already reduced system reliability in some regions!

California 2020: 491,000 customers lost power for up to 150 minutes during rolling blackouts

Preliminary Root Cause Analysis
Mid-August 2020 Heat Storm

October 6, 2020

- The climate change-induced extreme heat storm across the western United States resulted in the demand for electricity exceeding the existing electricity resource planning targets. The existing resource planning processes are not designed to fully address an extreme heat storm like the one experienced in mid-August.

California ISO

Prepared by:
California Independent System Operator
California Public Utilities Commission
California Energy Commission

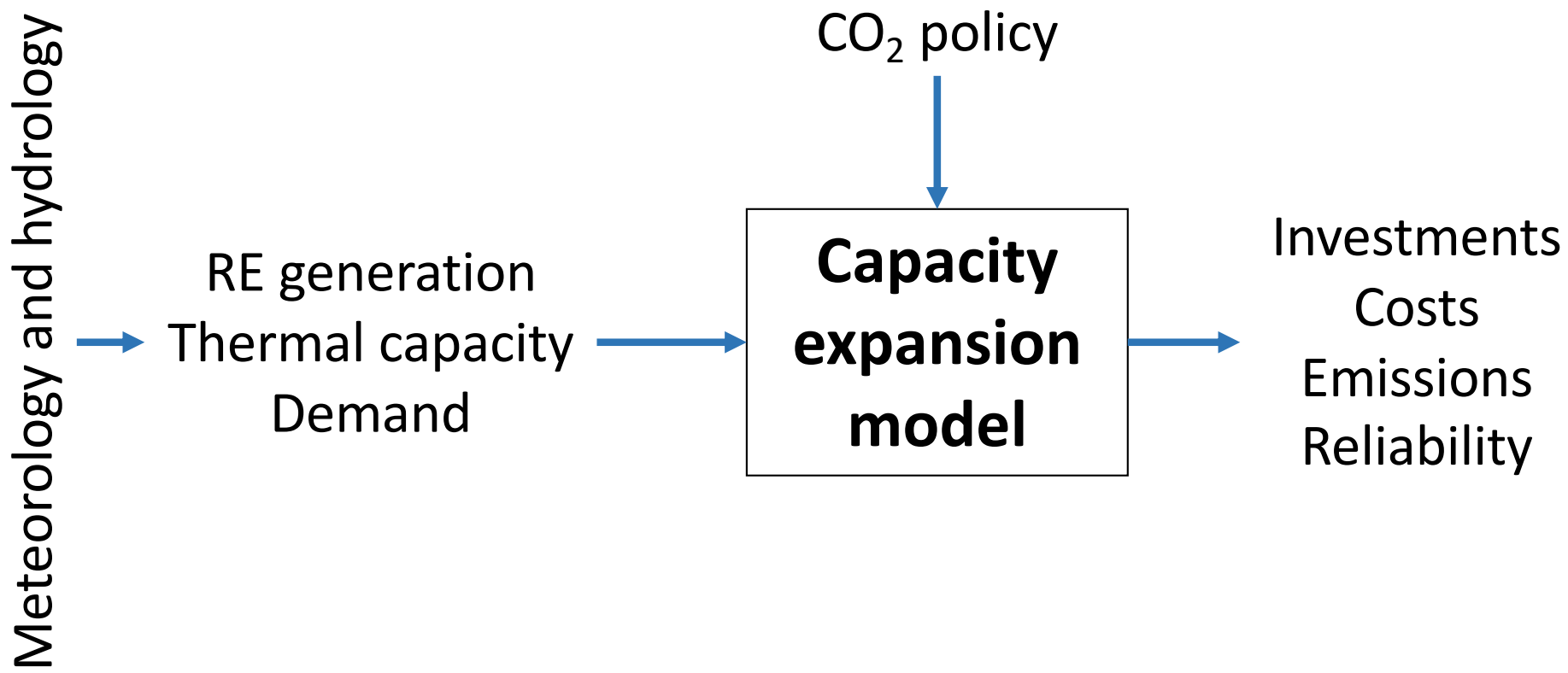
To plan power systems in research and practice, we typically:

Get high resolution **weather and hydrological** variables for a **historic** period (often 1 year).

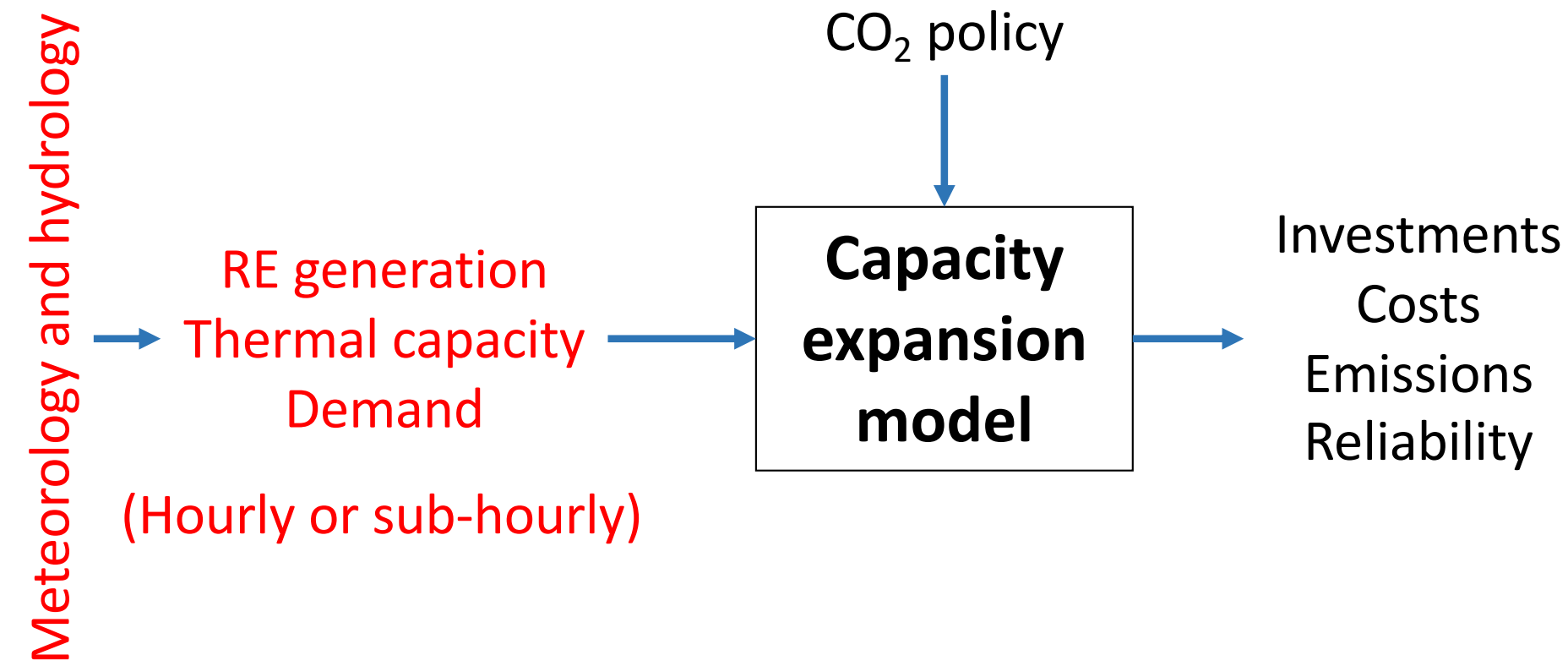
Forecast **demand** and **available capacities** based on **historic** data.

Use a **long-term, cost-minimizing planning model** to determine investments given forecasted demand, available capacities, and other inputs.

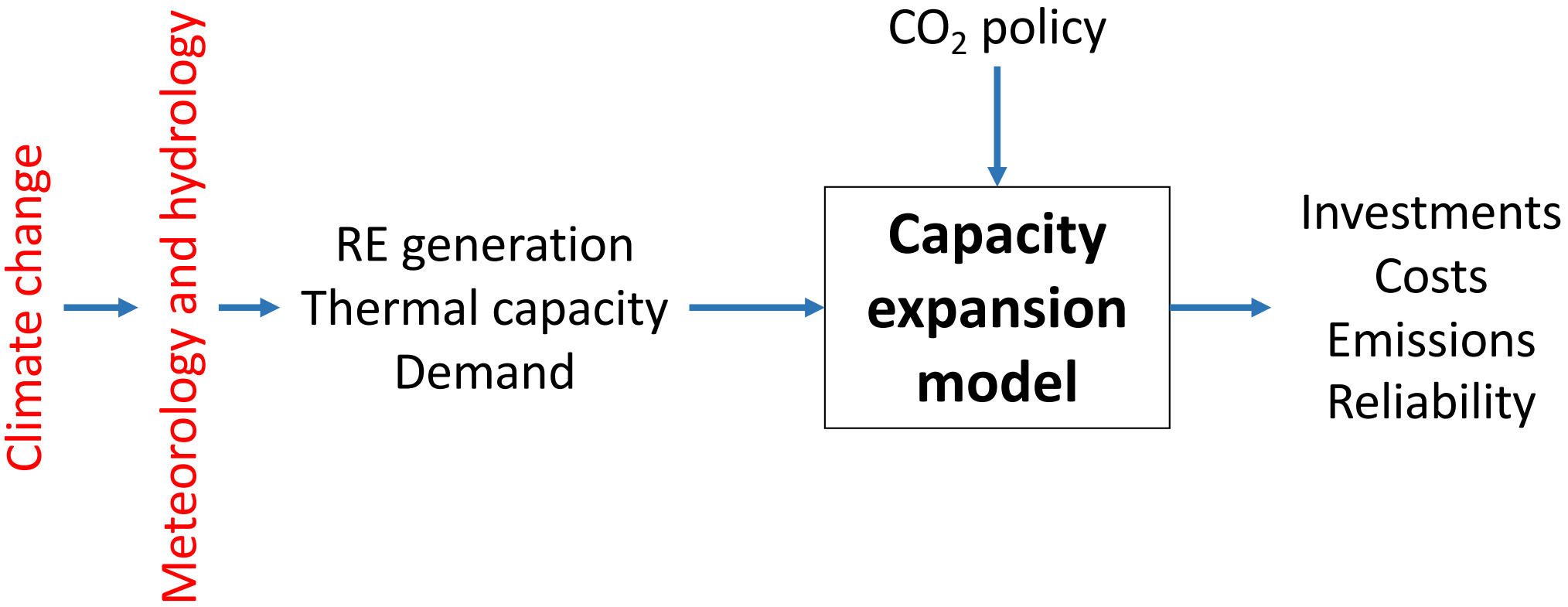
To plan power systems in research and practice, we typically:



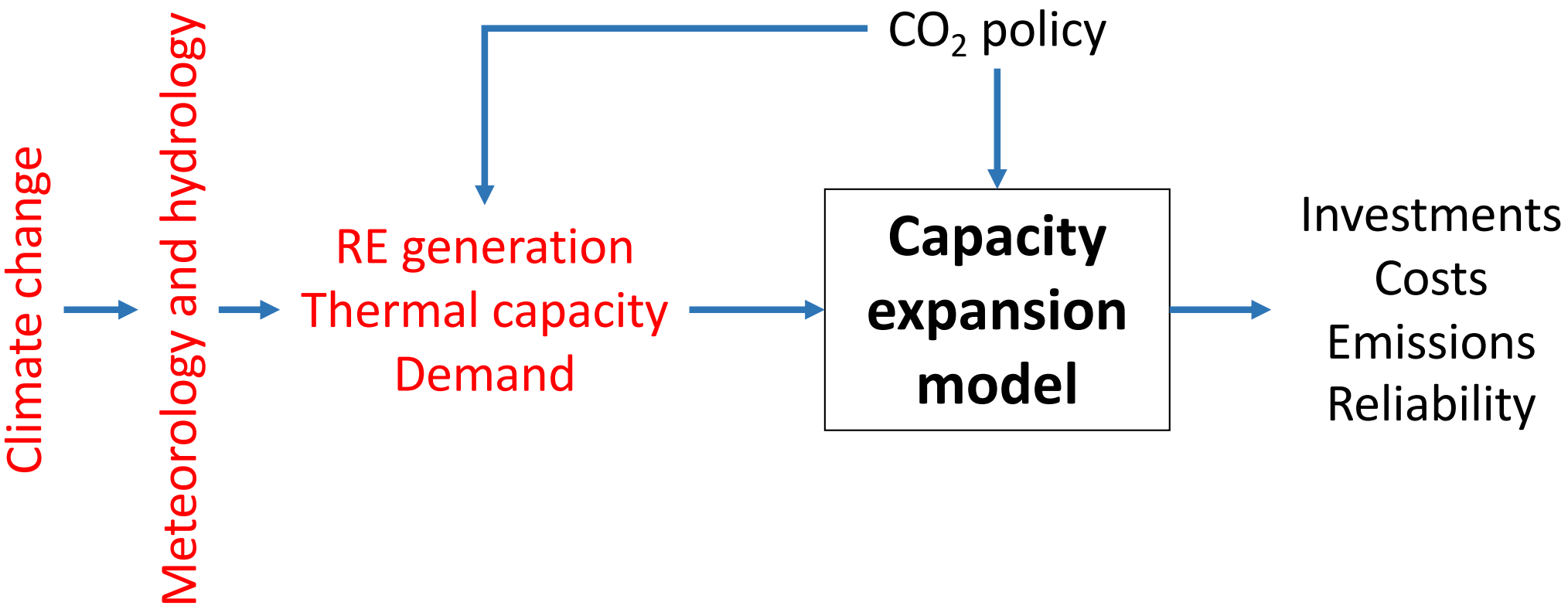
Through high spatial and temporal resolution in model inputs, we (try to) capture variable and extreme weather.



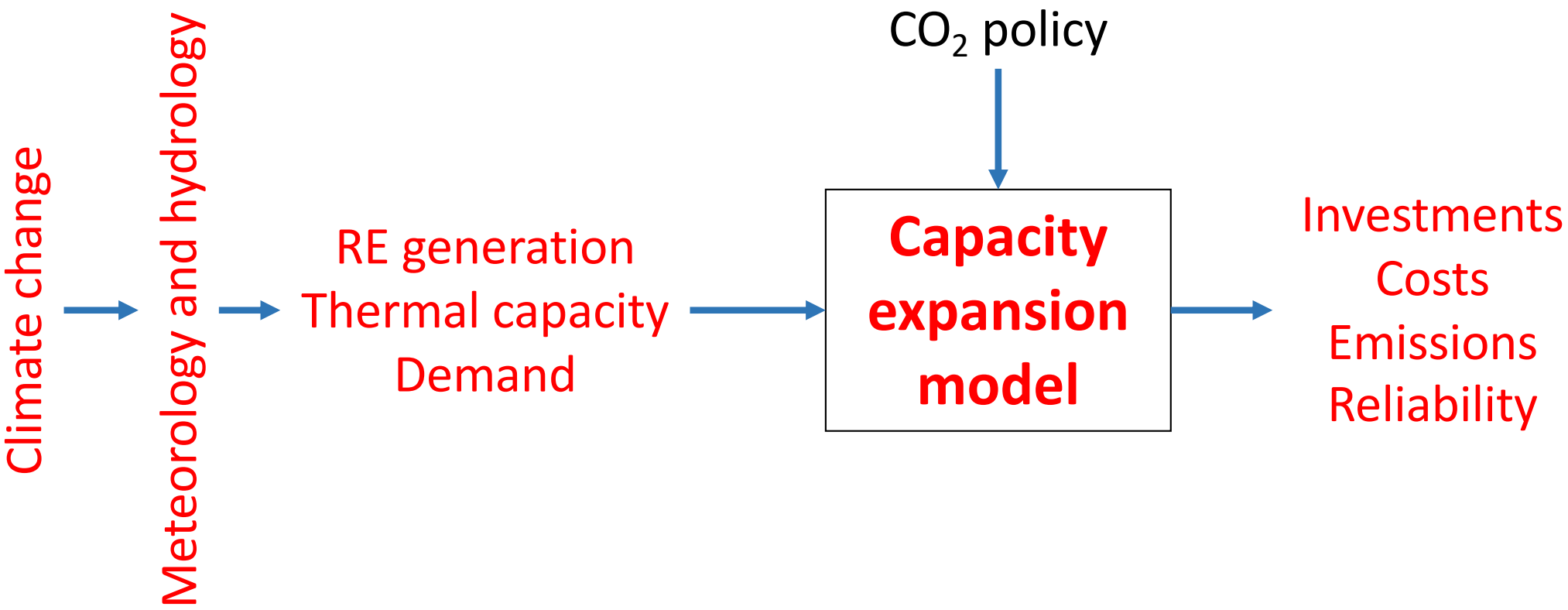
A straightforward approach to incorporating climate change in planning: modify meteorology and hydrology to reflect future conditions…



… then translate environmental changes to supply and demand changes, capturing CO_2 policy interactions…

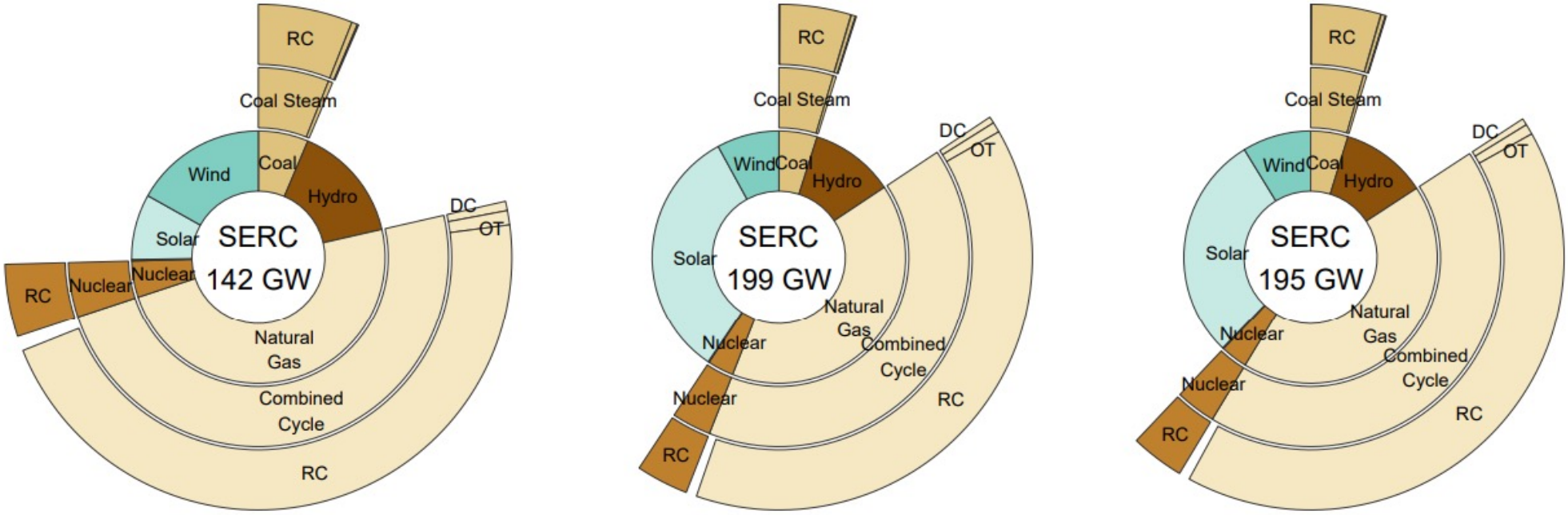


… then modify your model formulation.



A growing body of research takes this approach to analyze how climate change would alter planning decisions.

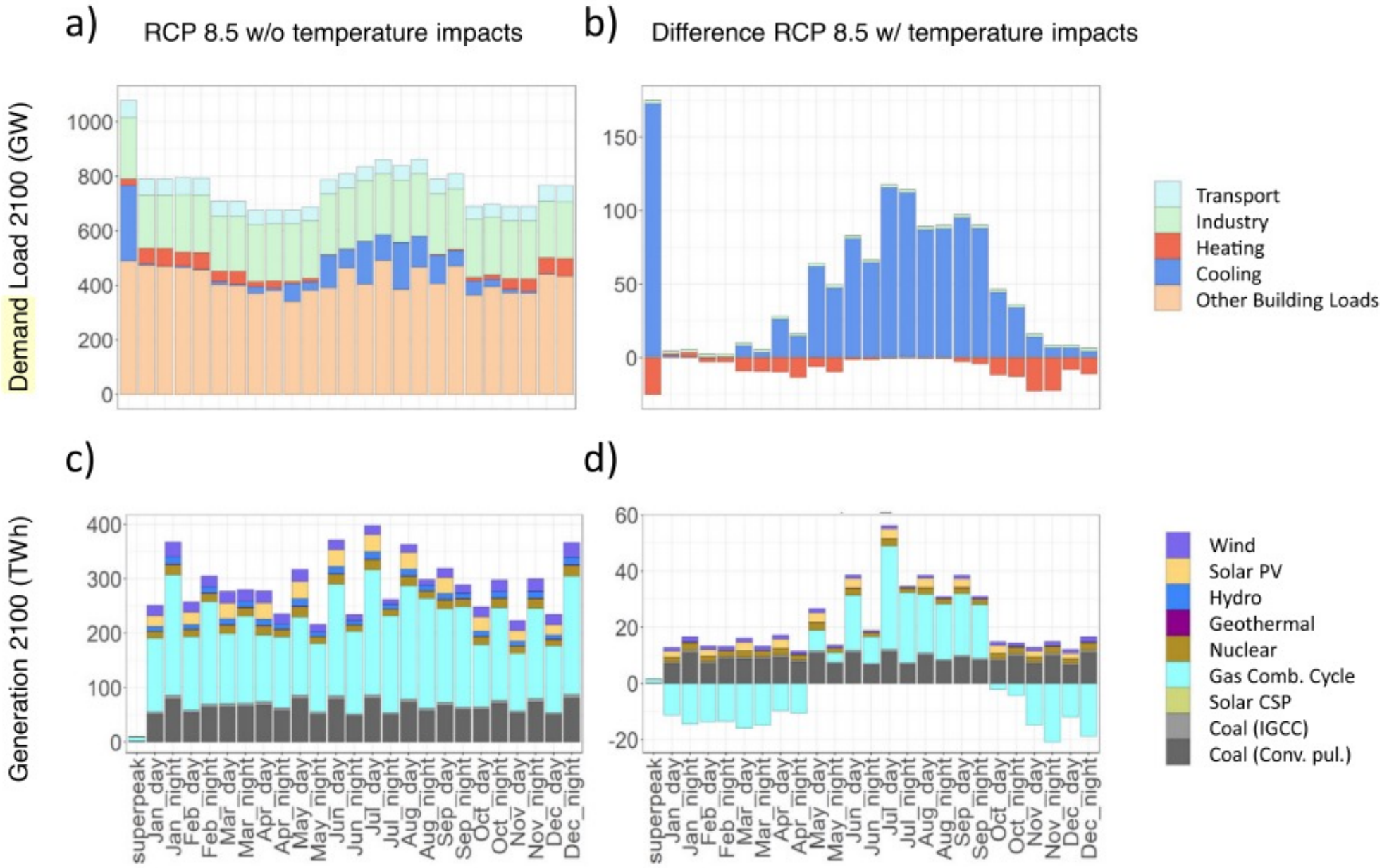
In the Southeast U.S., including climate impacts on demand, thermal plants, and hydropower in planning increases overall investment needs and displaces natural gas with solar capacity.



(a) Reference case (b) RCP 4.5 (c) RCP 8.5

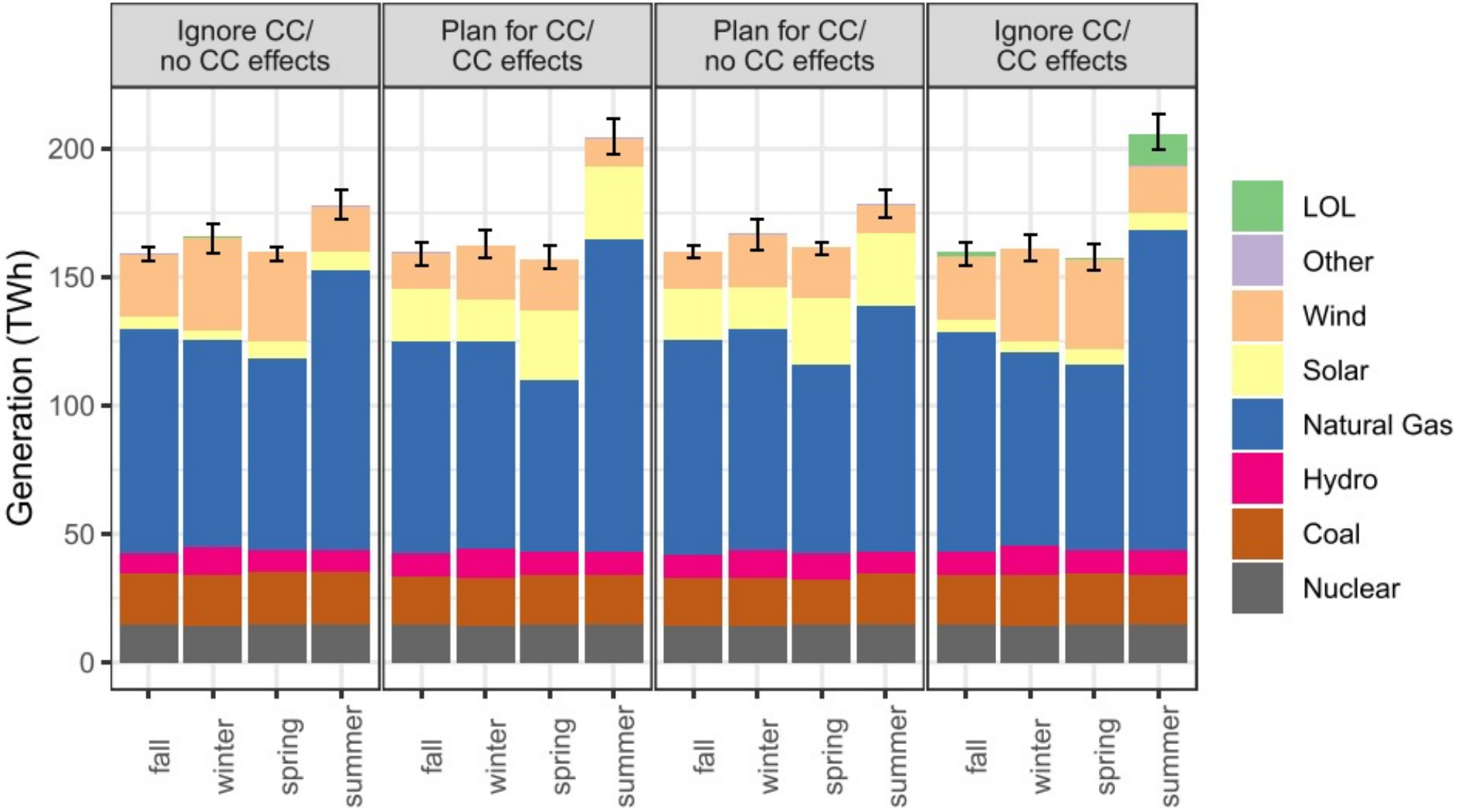
Fonseca et al., "Effects of Climate Change on Capacity Expansion Decisions of an Electricity Generation Fleet in the Southeast U.S.", *Env. Sci. & Tech.*, 2021

Across the U.S., including climate impacts on demand significantly increases generation needs.



Khan et al., "Impacts of long-term temperature change and variability on electricity investments", *Nat. Comms*., 2021

In the Southeast U.S., ignoring climate change in planning can result in significantly reduced reliability.



Fonseca et al., "Effects of Climate Change on Capacity Expansion Decisions of an Electricity Generation Fleet in the Southeast U.S.", *Env. Sci. & Tech.*, 2021

This approach of running the same type of planning models with future climate data faces two main challenges:

1. **Downscaling methods struggle to provide wind and solar data at desired spatiotemporal resolution.**

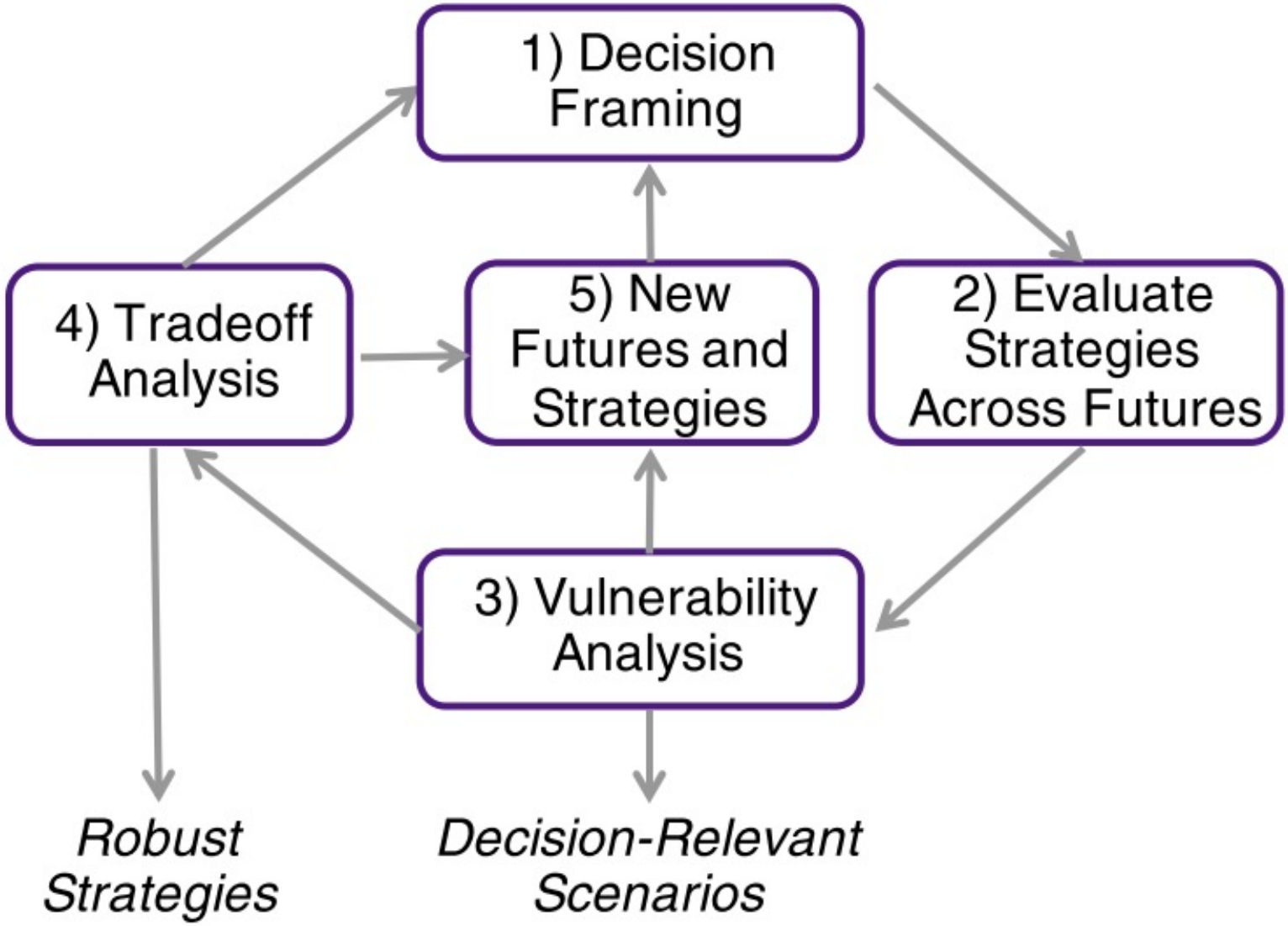
   Undermines value of traditional optimization planning approach.

2. **Deep uncertainty surrounds future climate change and its impacts.**

   Optimal system might perform poorly under future potential climate realizations.

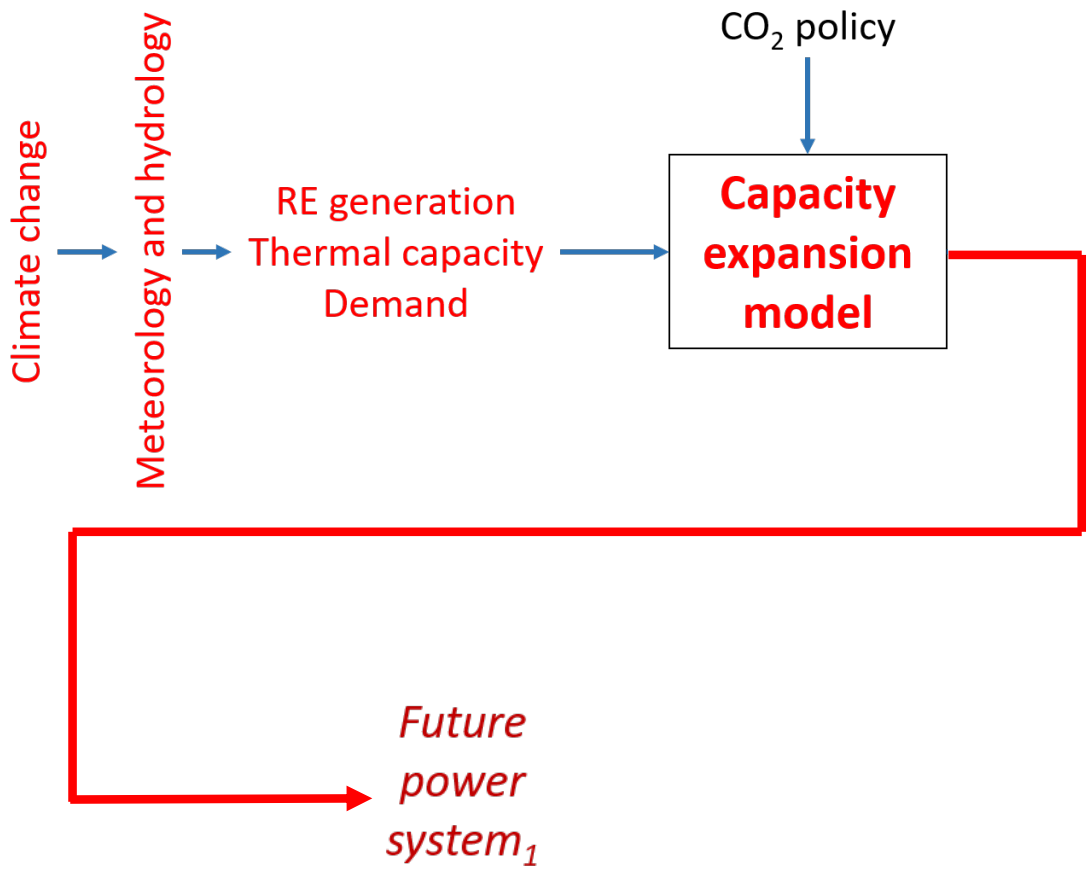
Robust decision frameworks can overcome these challenges by finding systems that perform well across future climate realizations.

Robust decisionmaking (RDM) stress-tests solutions and identifies trade-offs between decisions and objectives given different realizations of uncertainties.

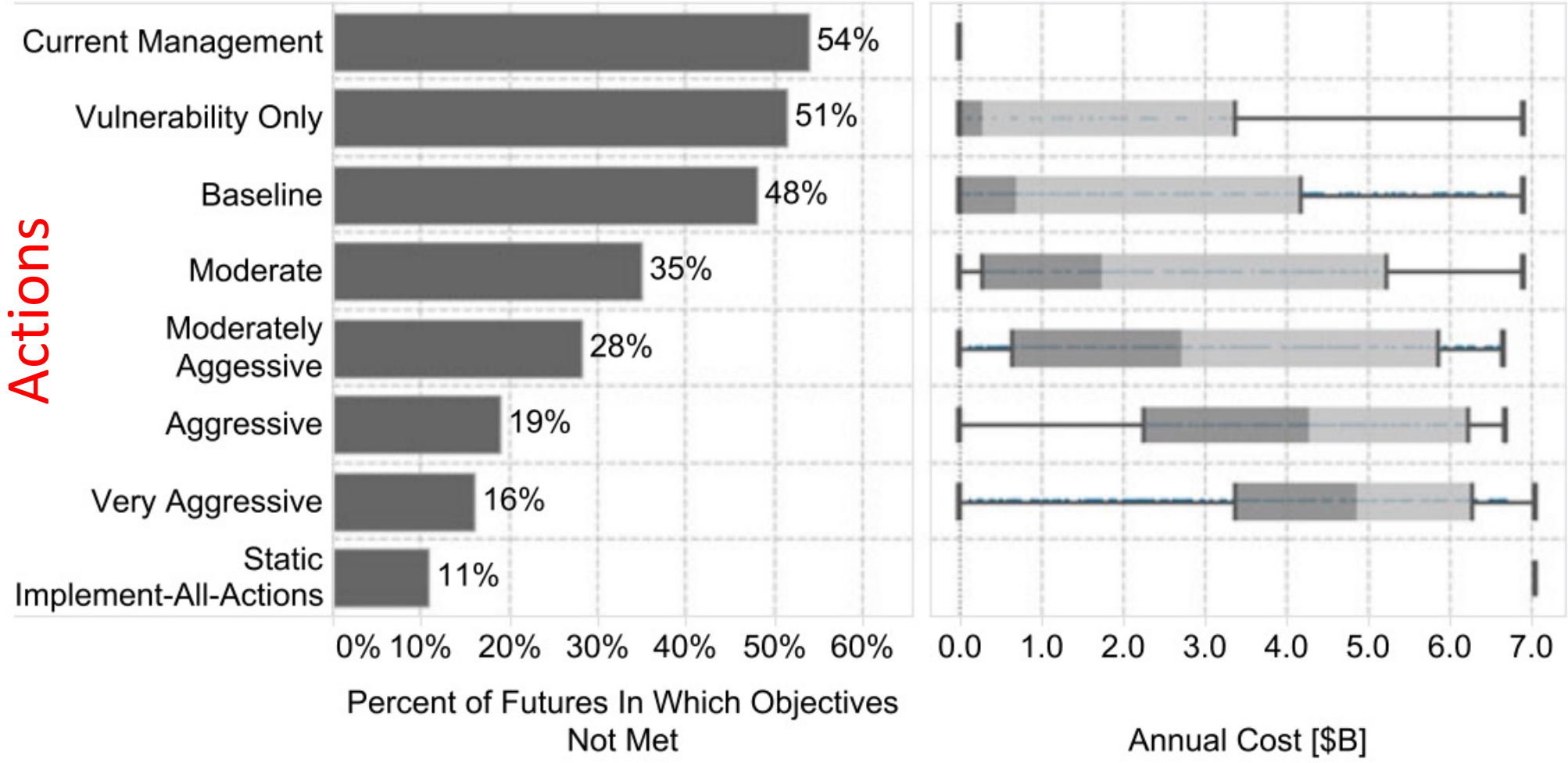


Marchau et al., *Decision Making under Deep Uncertainty*, 2019

In our context, RDM allows us to stress-test the cost and reliability of alternative future power systems to different climate realizations.



RDM has been applied in other contexts, e.g. for long-term water resource planning in Colorado River Basin.

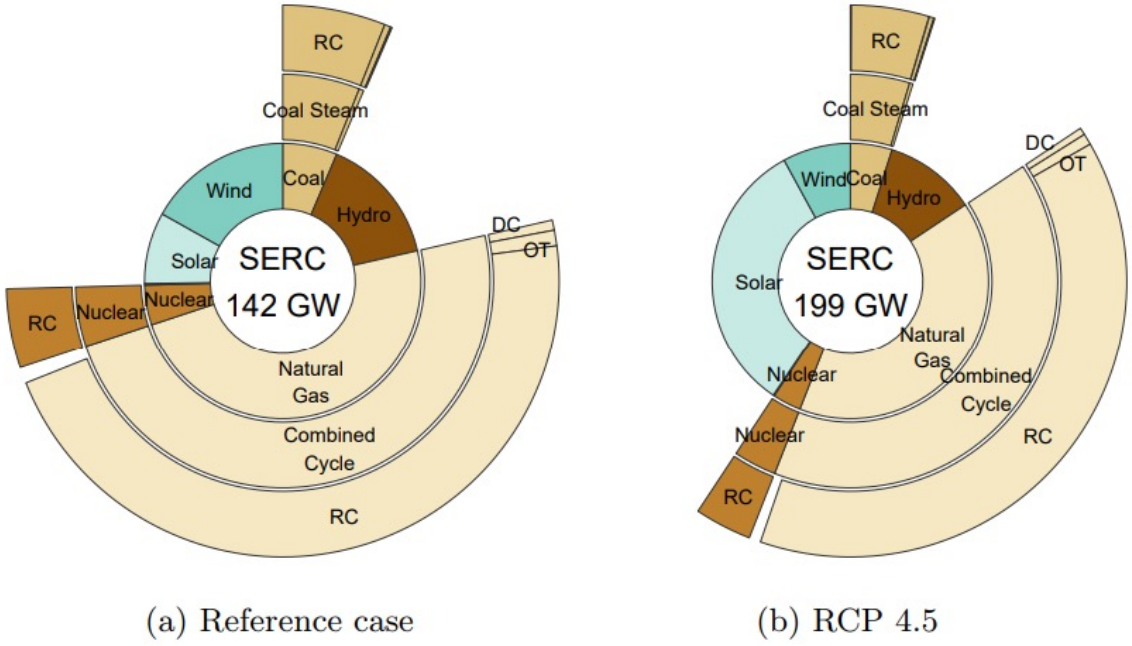


Marchau et al., *Decision Making under Deep Uncertainty*, 2019

Accounting for climate change impacts in power system planning could significantly shift investment decisions. Outages could occur if these impacts are ignored.

Recent papers have incorporated diverse supply- and demand-side impacts of climate change into the traditional, optimization-based planning framework.

The value of this framework is limited by downscaling limitations and deep uncertainty surrounding the impacts of climate change.



(a) Reference case

(b) RCP 4.5

Robust decisionmaking and other decision frameworks offer a valuable new path forward for identifying systems that will perform well across potential climate realizations.

Thank you for your attention!

Please let me know your questions and comments.

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