Future Grid

How to make decisions under uncertainty

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ClimateWisdom™

The factors affecting our future grid in 2050

Factor 1: Higher or lower **Temperature** relative to expected

Factor 2: Higher or lower **relative cost of Renewables**

Factor 3: More **Regional Grid** or less than expected

Factor 4: More or less **Load Growth** than expected


Temperature
in 2050

Why Temperature as a factor?

Higher than expected temperatures mean:

More AC Load

Lower efficiency for solar, wind

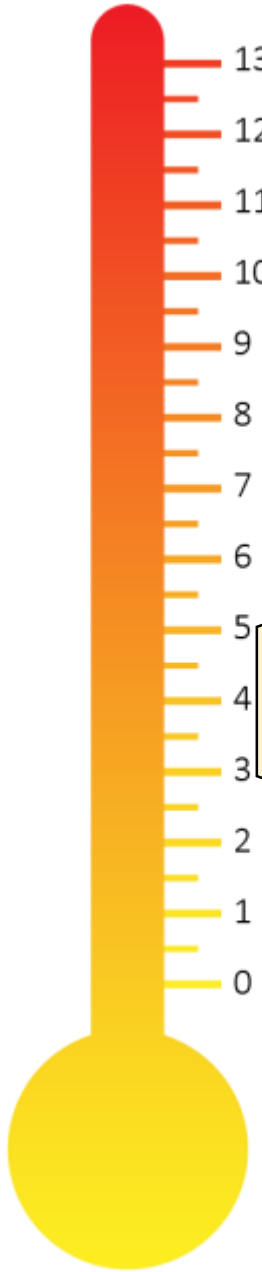
More powerful storms

More fires and more severe fires

Health effects

Resulting in increased costs

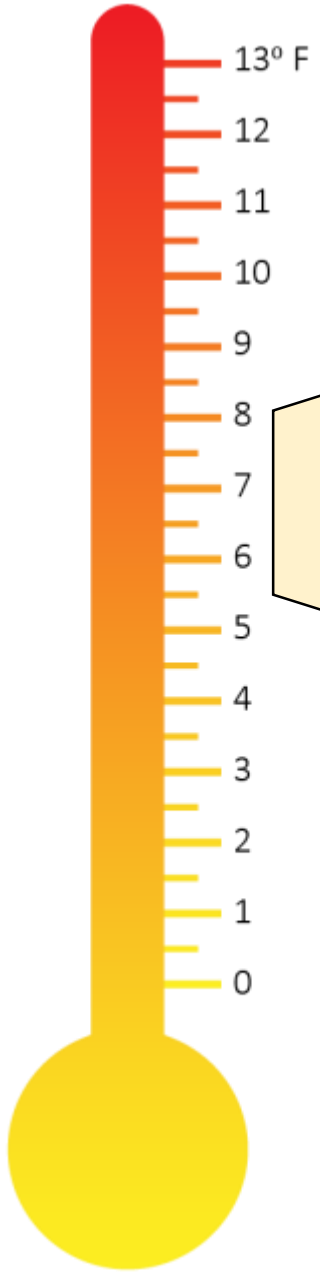
California Temperature Scenarios?



Lower Warming Range (3-5.5F)

- 30-60% loss in Sierra snowpack
- 6-14 inches of sea level rise
- 3-6% increase in electricity demand
- 10-35% increase risk of large wildfires

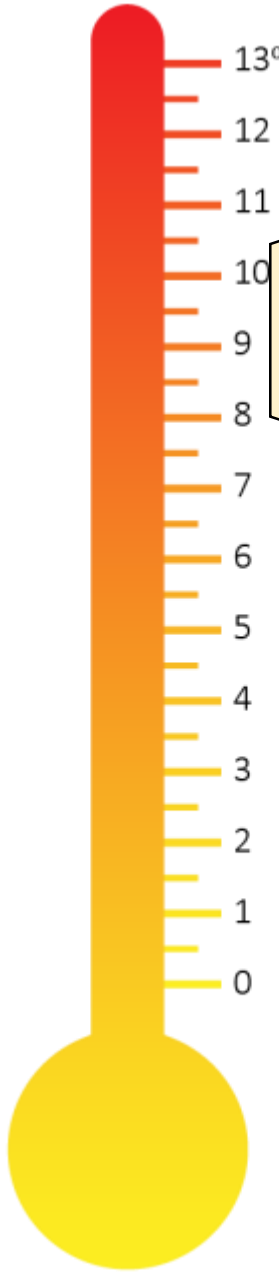
California Temperature Scenarios?



Medium Warming Range (5.5-8F)

- 70-80% loss in Sierra snowpack
- 14-22 inches of sea level rise
- 10% increase in electricity demand
- 55% increase risk of large wildfires

California Temperature Scenarios?



Higher Warming Range (8-10.5F)

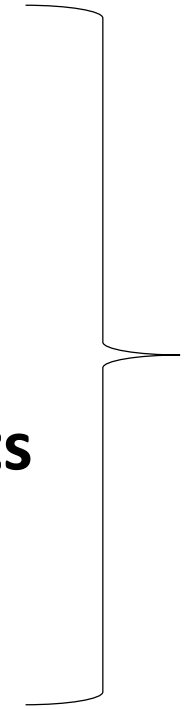
- 90% loss in Sierra snowpack
- 22-30 inches of sea level rise
- 20% increase in electricity demand

Relative Cost of Renewables by 2050

Why relative cost of Renewables as a factor?

Will affect adoption

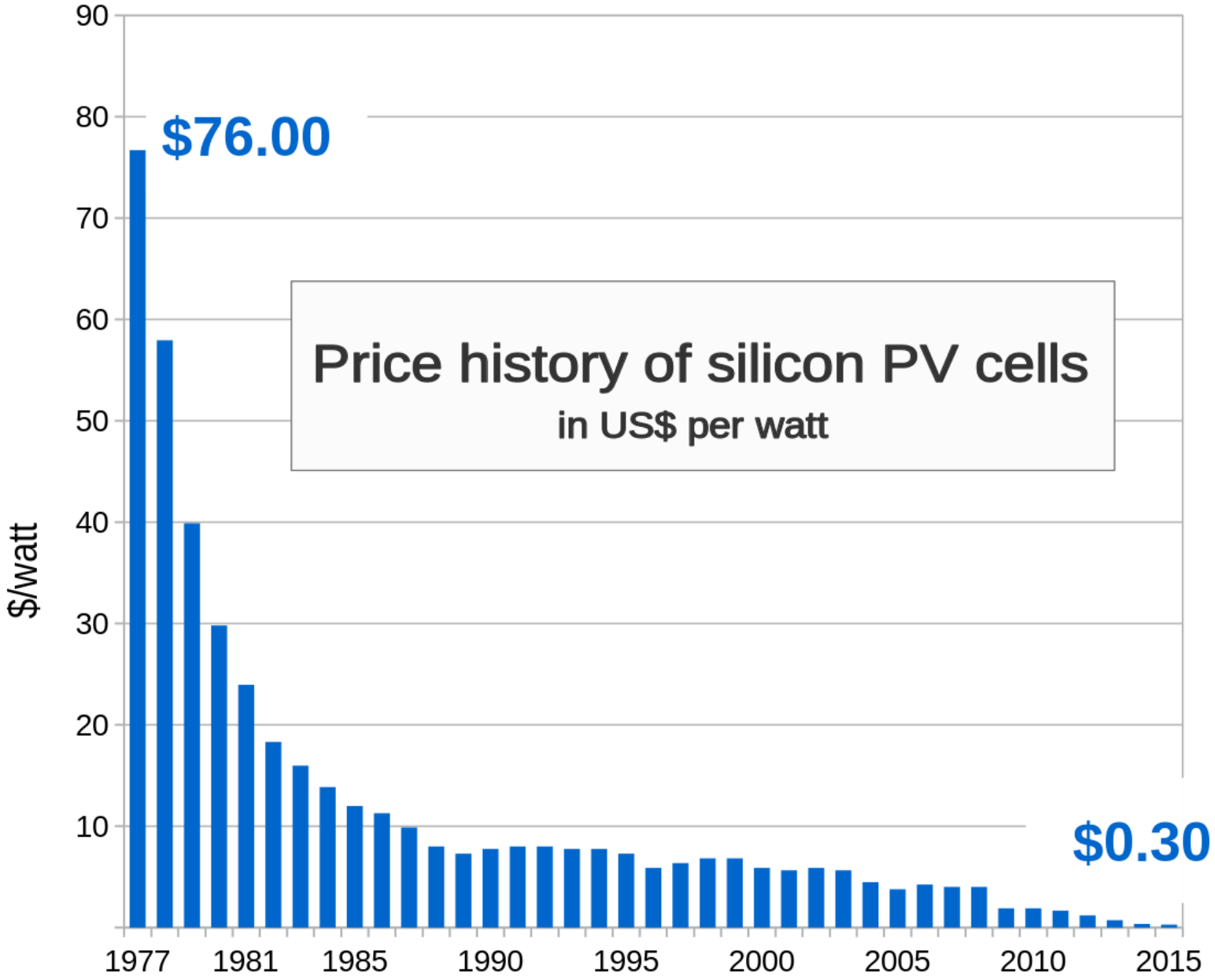
Will affect the cost of meeting environmental targets



Affects budget

History

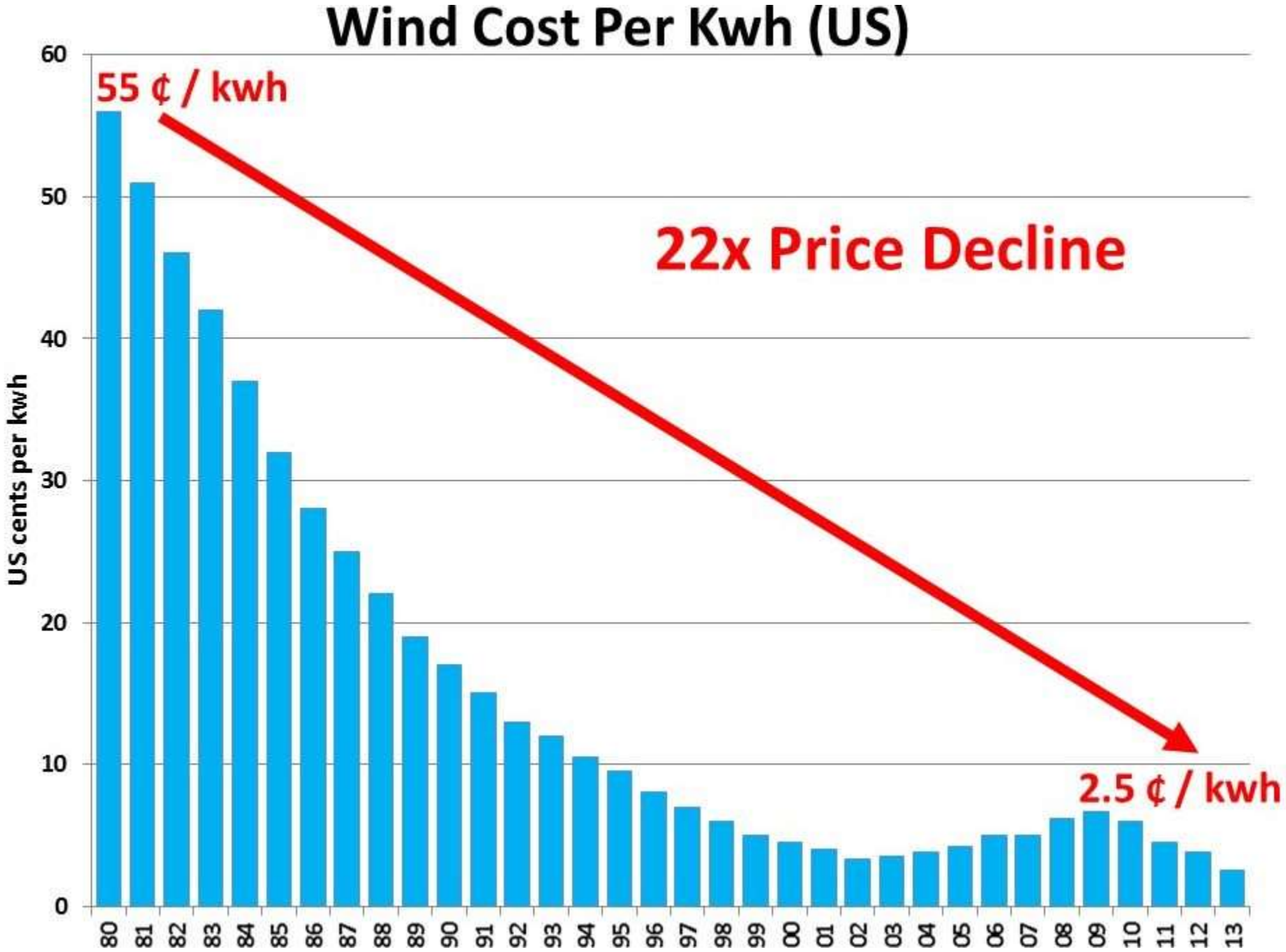
Solar costs continue to decrease materially



Source: Bloomberg New Energy Finance & pv.energytrend.com

History

Wind costs continue to decrease materially



Source: DoE

The Future

This year's forecast from BNEF sees
solar energy costs dropping a further 66% by 2040,
and **onshore wind by 47%,**

with **renewables undercutting** the majority of
existing **fossil power stations by 2030**.

Source: Bloomberg June 15, 2017

Battery Storage

Small-scale batteries installed by households and businesses alongside PV systems will account for **57% of storage worldwide by 2040.**

Battery costs are **decreasing** by 66% by 2030

Source: Bloomberg Energy Finance

Regional Collaboration

Why Regional Collaboration as a factor?

More regional integration:

Reduces costs balancing supply and demand

Diversifies source and location of supply

Enables broader transformation

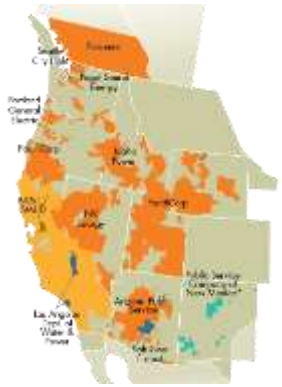
Increases reliability and resiliency

Possible cost reductions

Why Regional Collaboration as a factor?

Benefits by Level of Regional Coordination

Balancing area operations



Sub-hourly economic dispatch

Day-of operations and residual unit commitment

Day-ahead trading and unit commitment

Transmission planning and resource procurement

Regional Organization

Extended Day-Ahead

Energy Imbalance Market

Load Growth

Why Load Growth as a factor?

Load Growth:

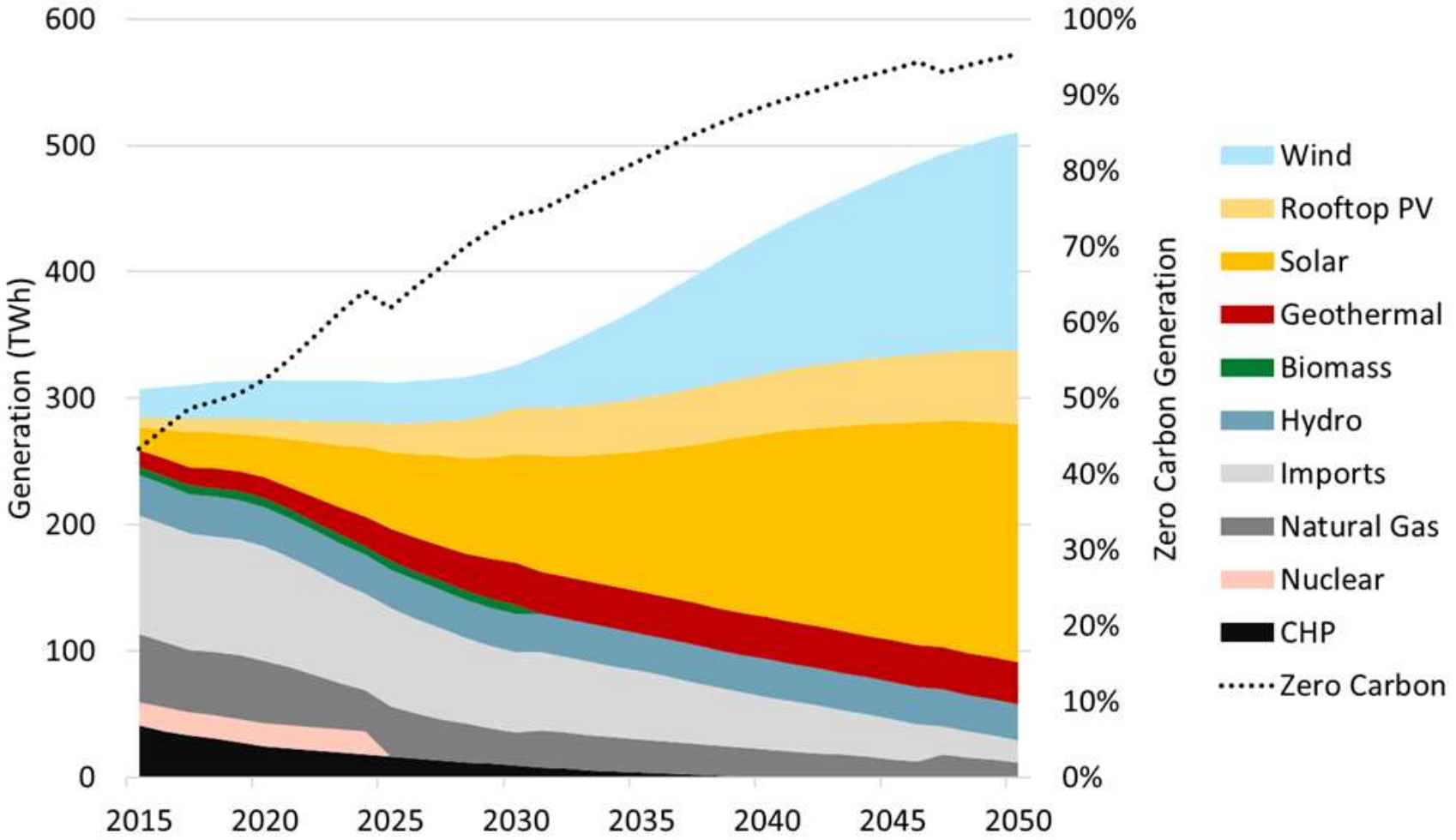
Due to sector switching

Due to temperature sensitive loads

Supply efficiency

Effects costs and provides possible opportunities

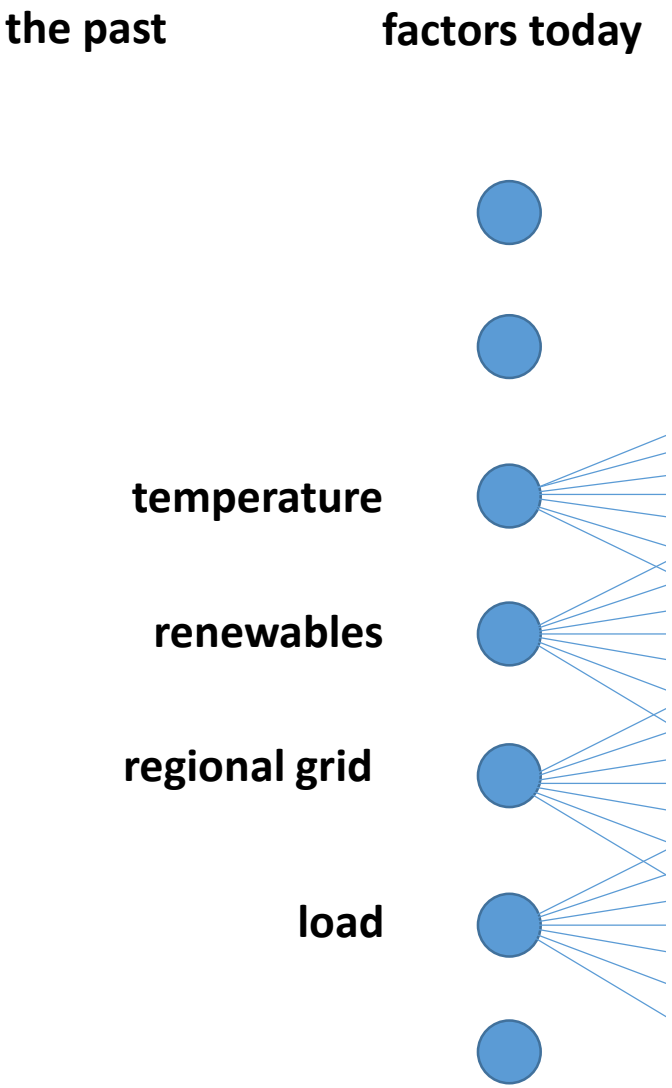
Demand for electricity is expected to increase as other sectors electrify to decarbonize



Source: https://www.ethree.com/wp-content/uploads/2018/06/Deep_Decarbonization_in_a_High_Renewables_Future_CEC-500-2018-012-1.pdf

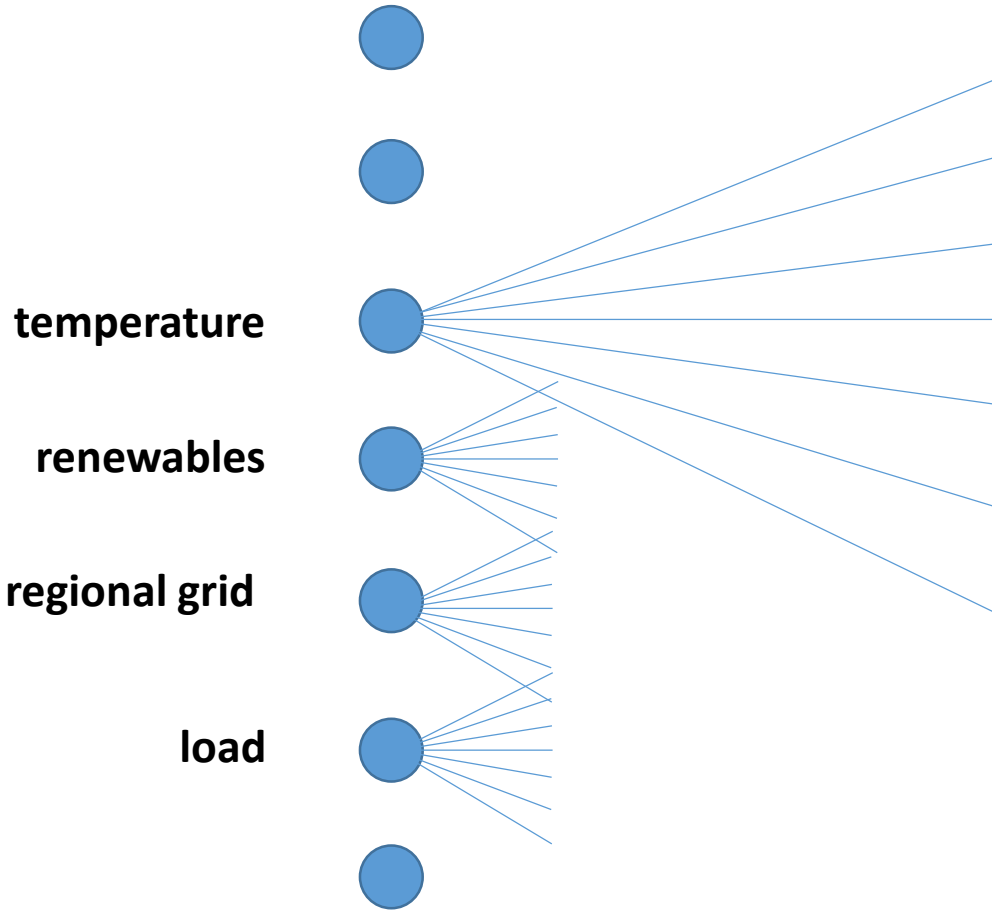
How to generate **forward looking scenarios**

Factor Uncertainty



Factor Uncertainty

the past **factors today** **factors in 2050**



Factor Uncertainty

the past

factors today

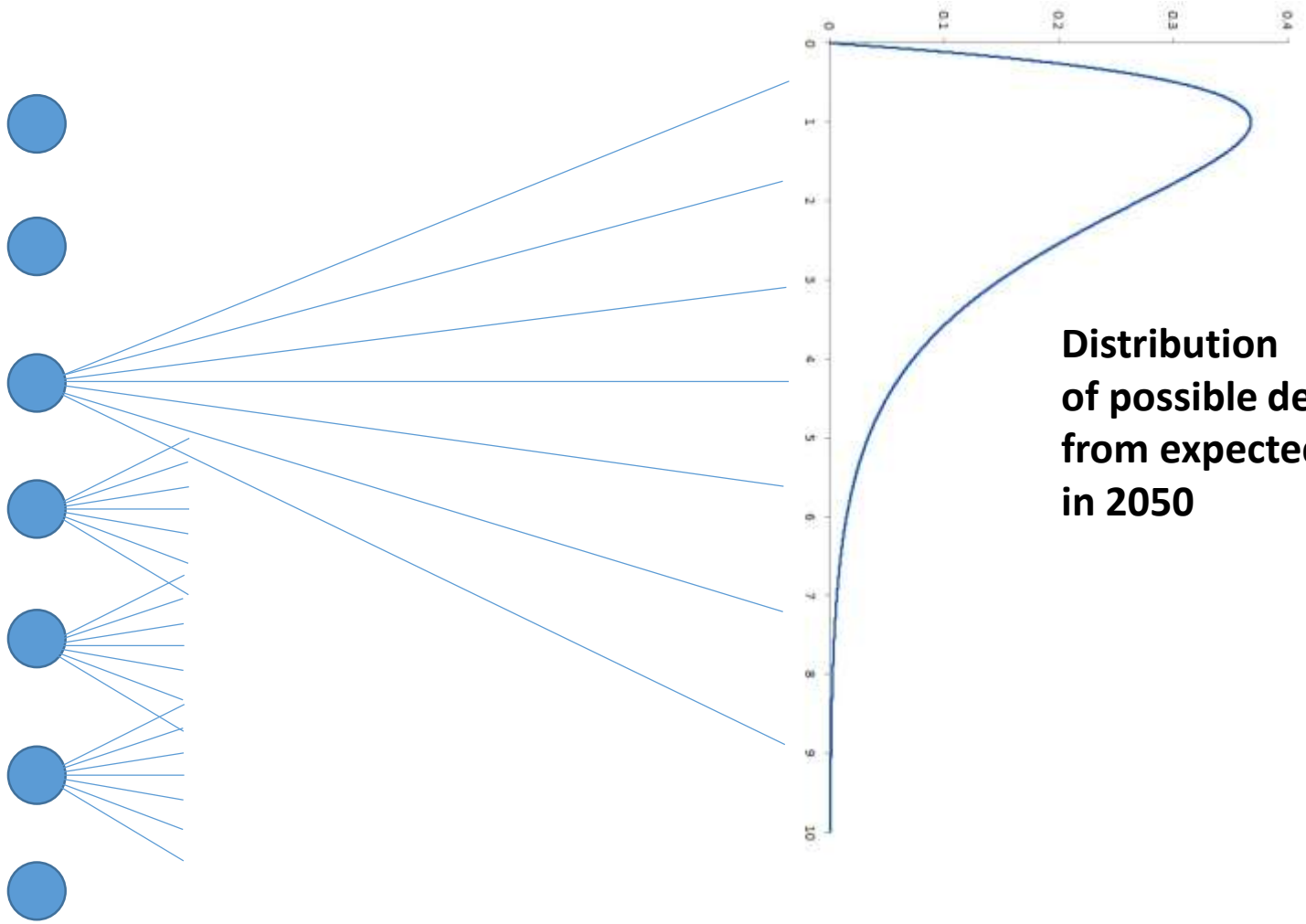
factors in 2050

temperature

renewables

regional grid

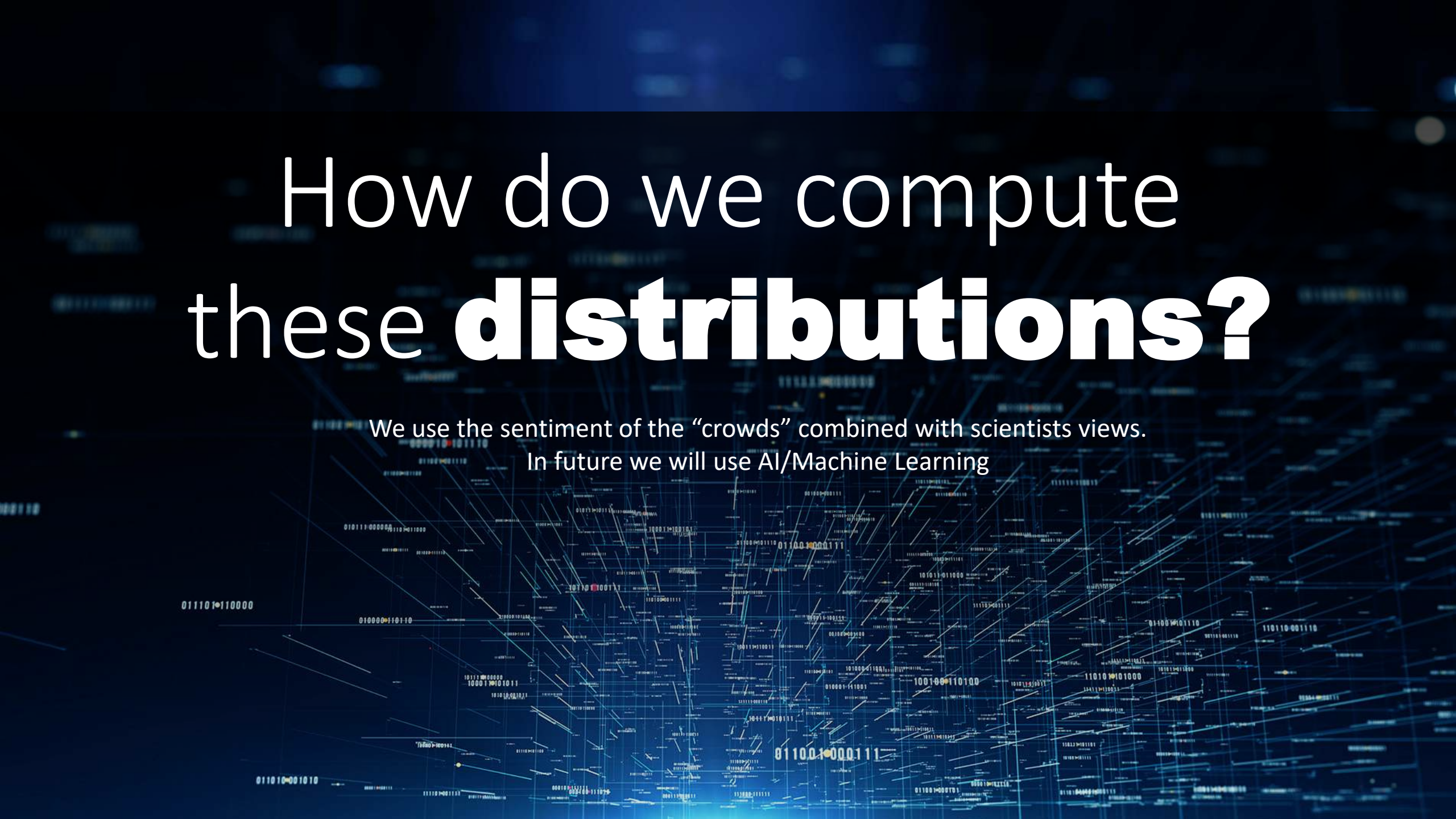
load



Distribution
of possible deviations
from expected temperature
in 2050

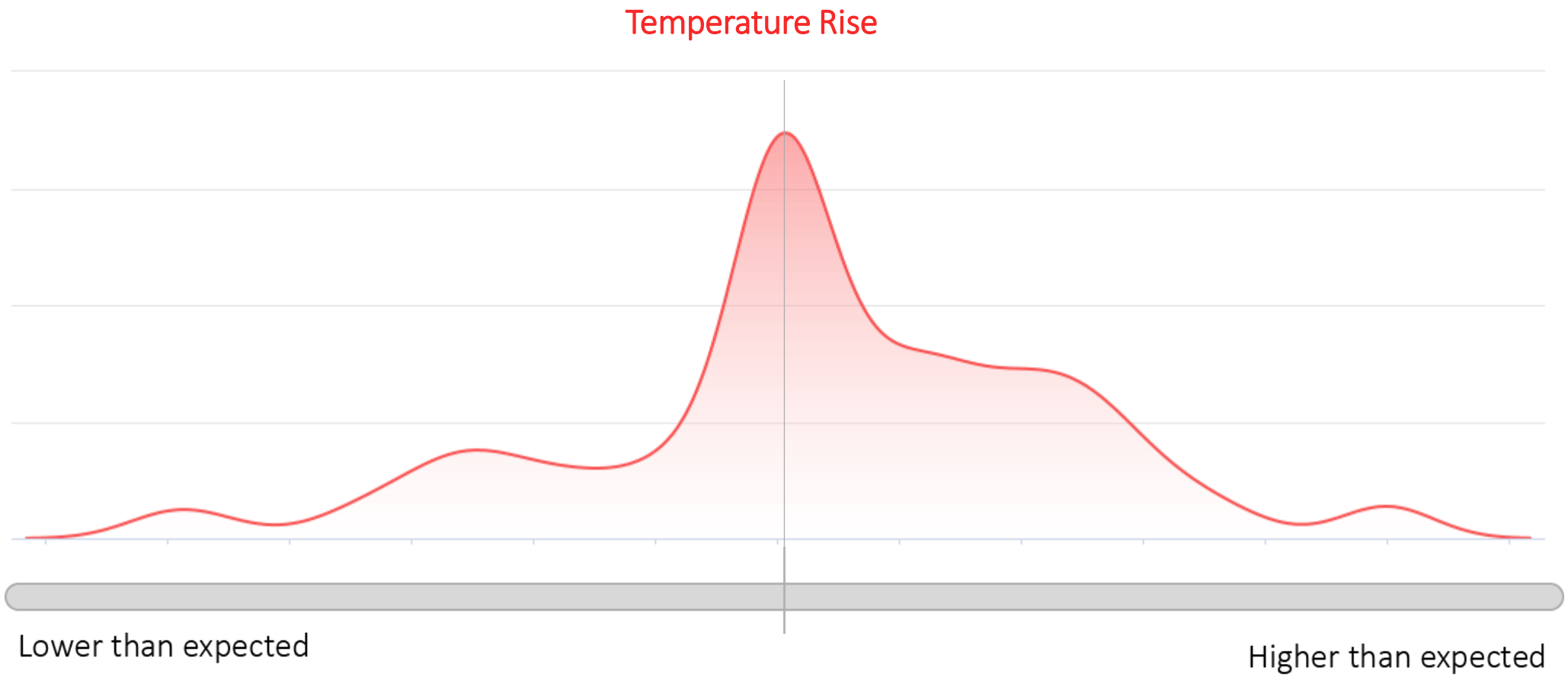
How do we compute these **distributions?**

We use the sentiment of the “crowds” combined with scientists views.
In future we will use AI/Machine Learning

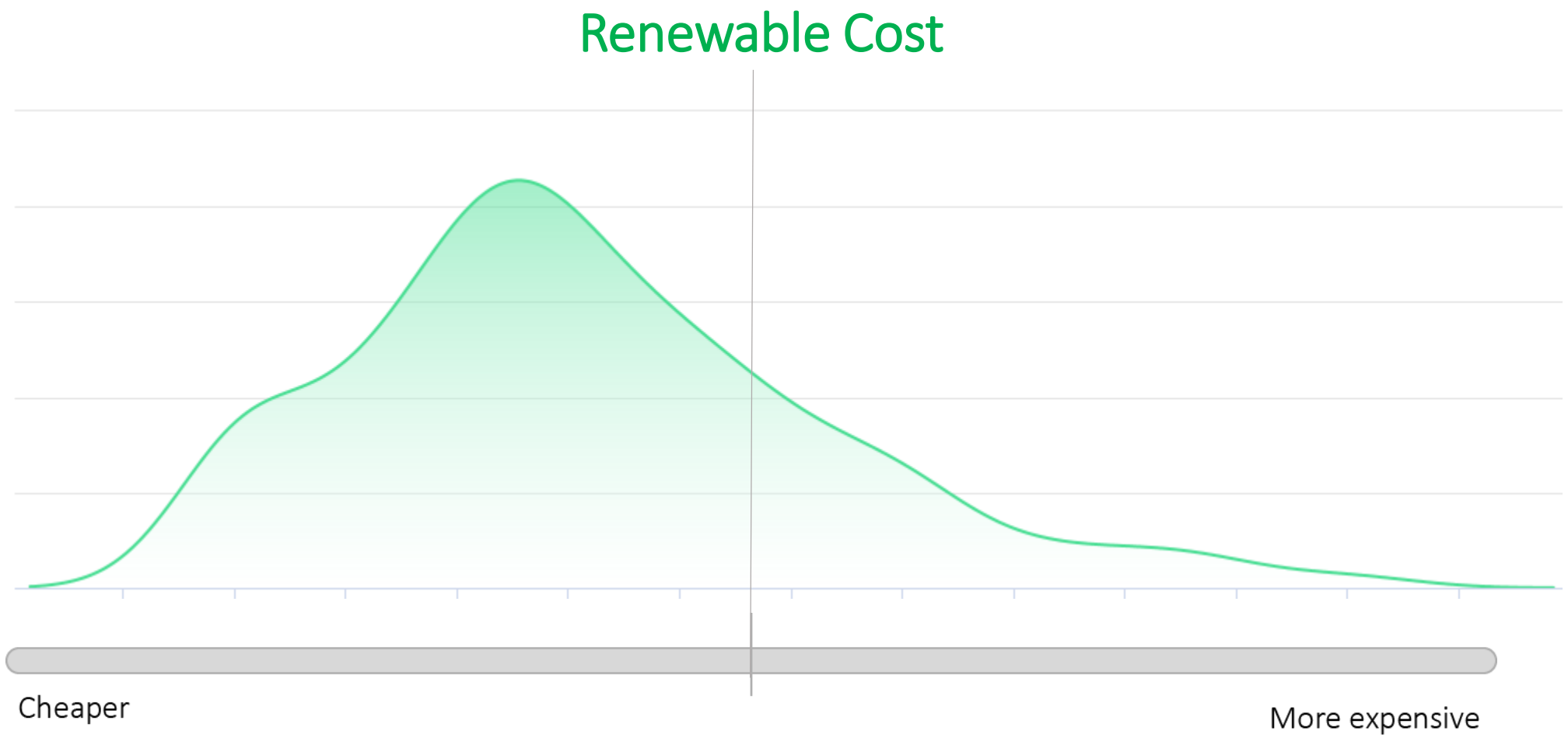


Studies indicate that by 2050 temperatures are expected to rise by approximately 4 degrees F.

What do you predict the temperature change to be?

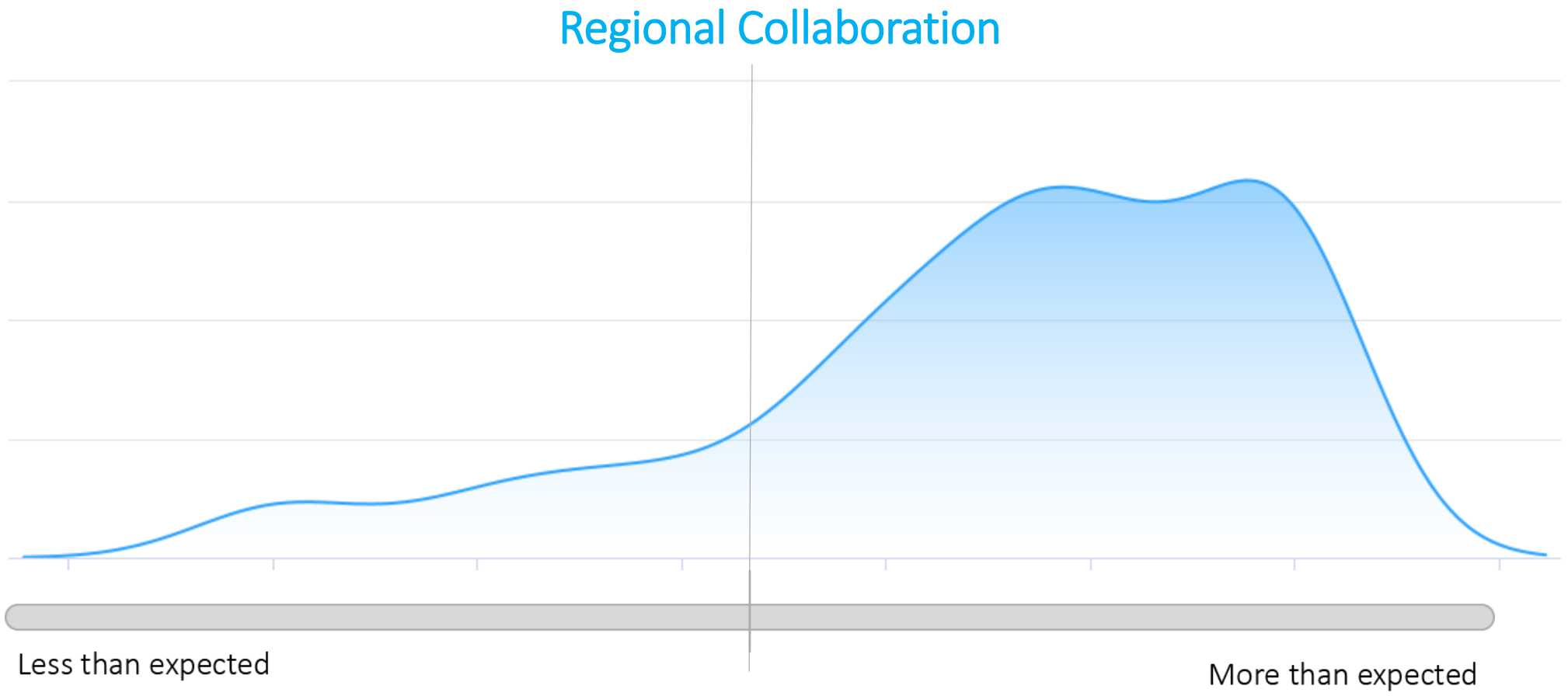


By 2050, the cost of renewable energy (without subsidies) compared to the cost of conventional resources will be…



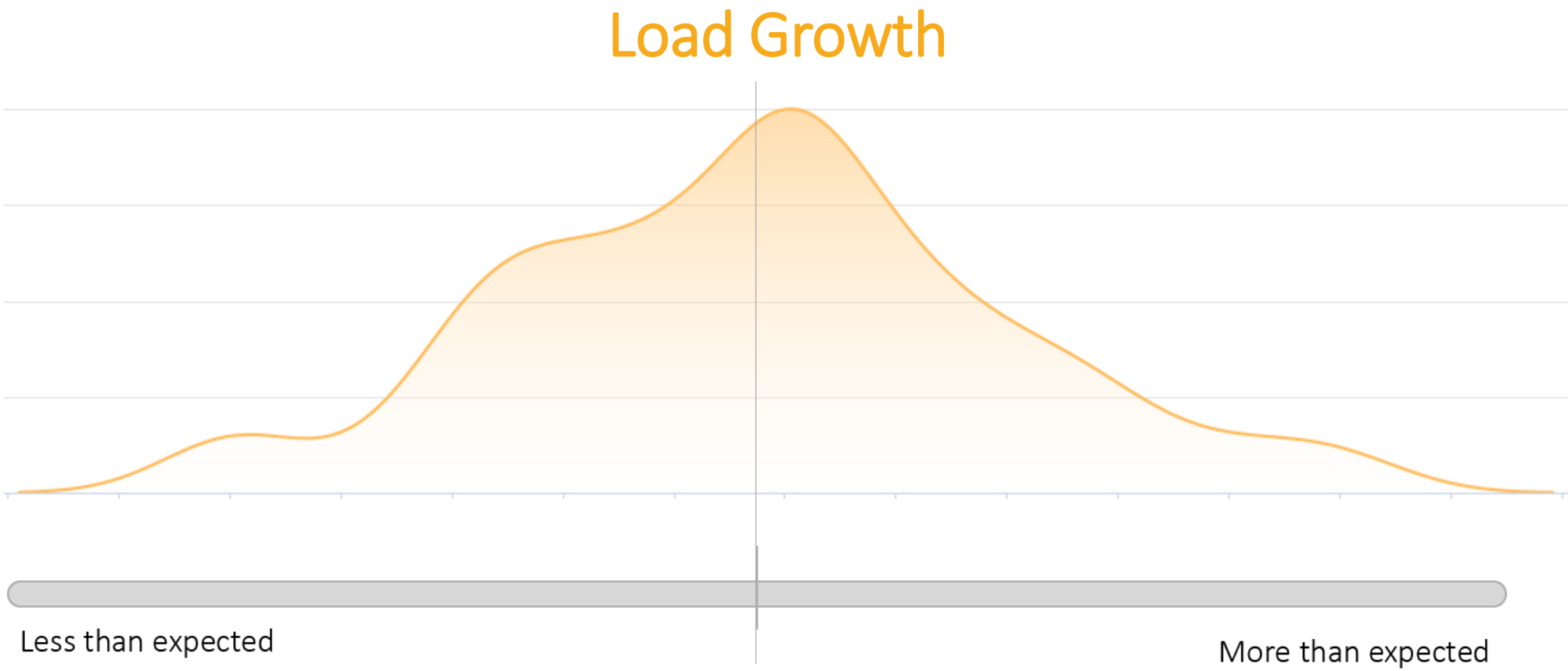
By 2050, it is expected that regional collaboration across the West could evolve from the existing Energy Imbalance Market to an expanded participation in the Day-Ahead Market to full participation options with a single ISO/RTO in the West.

What level of regional collaboration do you expect?



By 2050, annual demand is expected to increase by approximately 60% compared to our current demand levels.

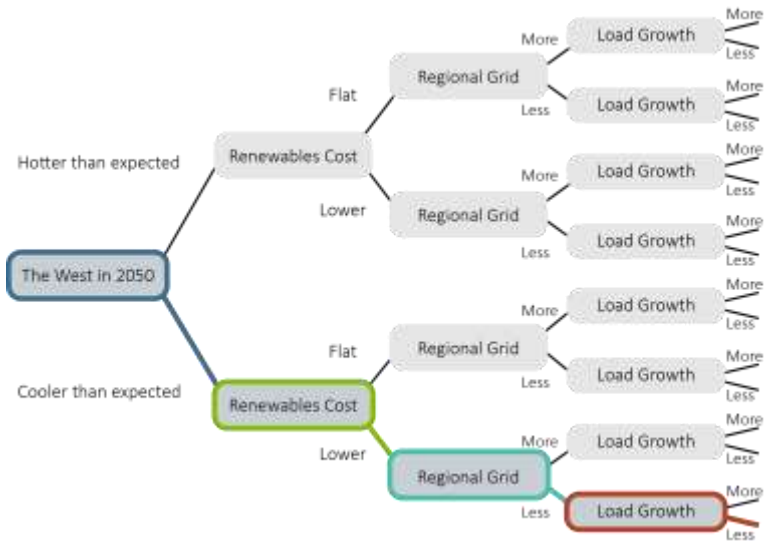
What do you expect the load growth to be?

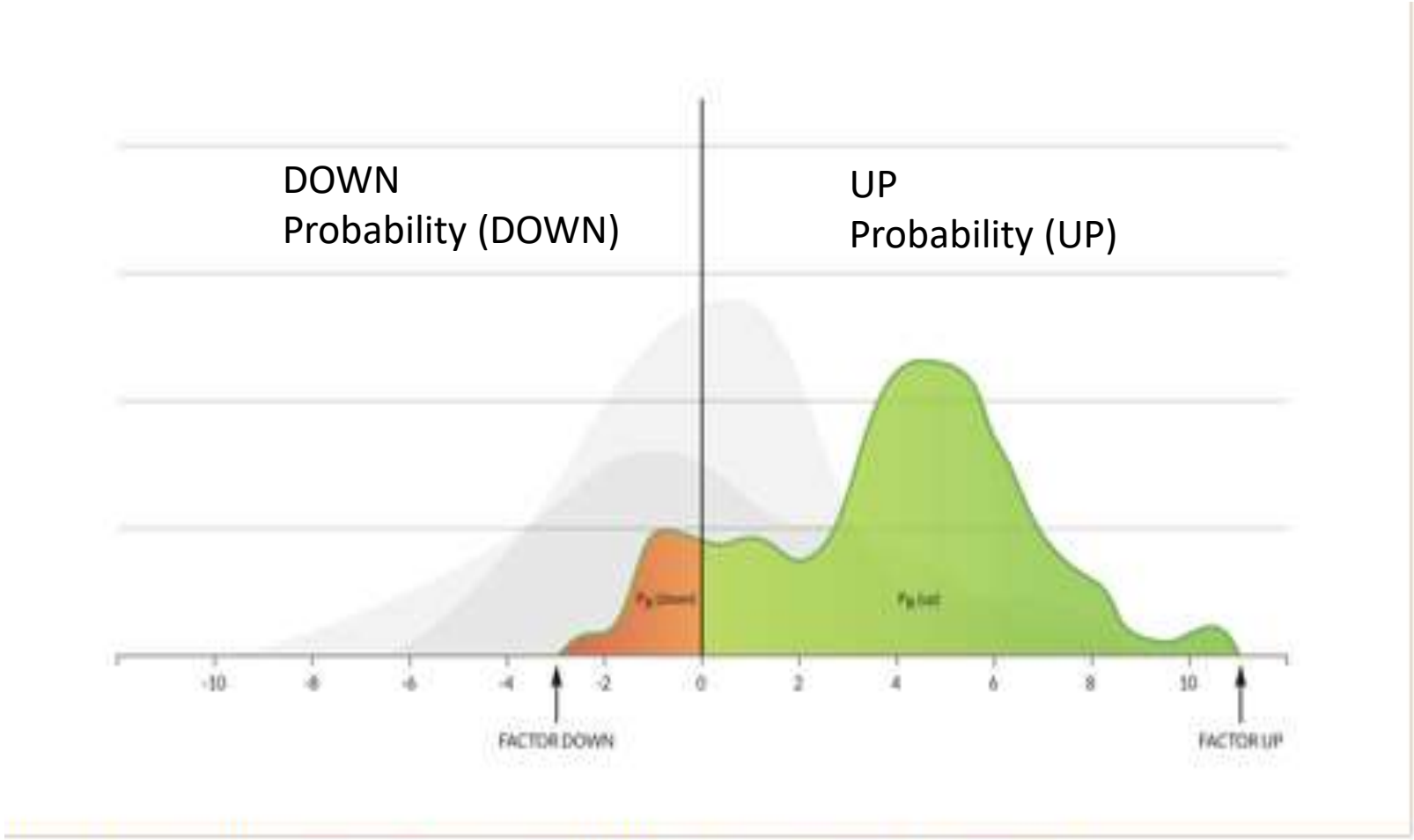


How do we get **values** for the Scenario Tree?

A clue comes from looking at the uncertainty in the factors

Filling in the data needed to evaluate the tree





Useful information embodied in the forward distribution

Valuing Scenario Outcomes

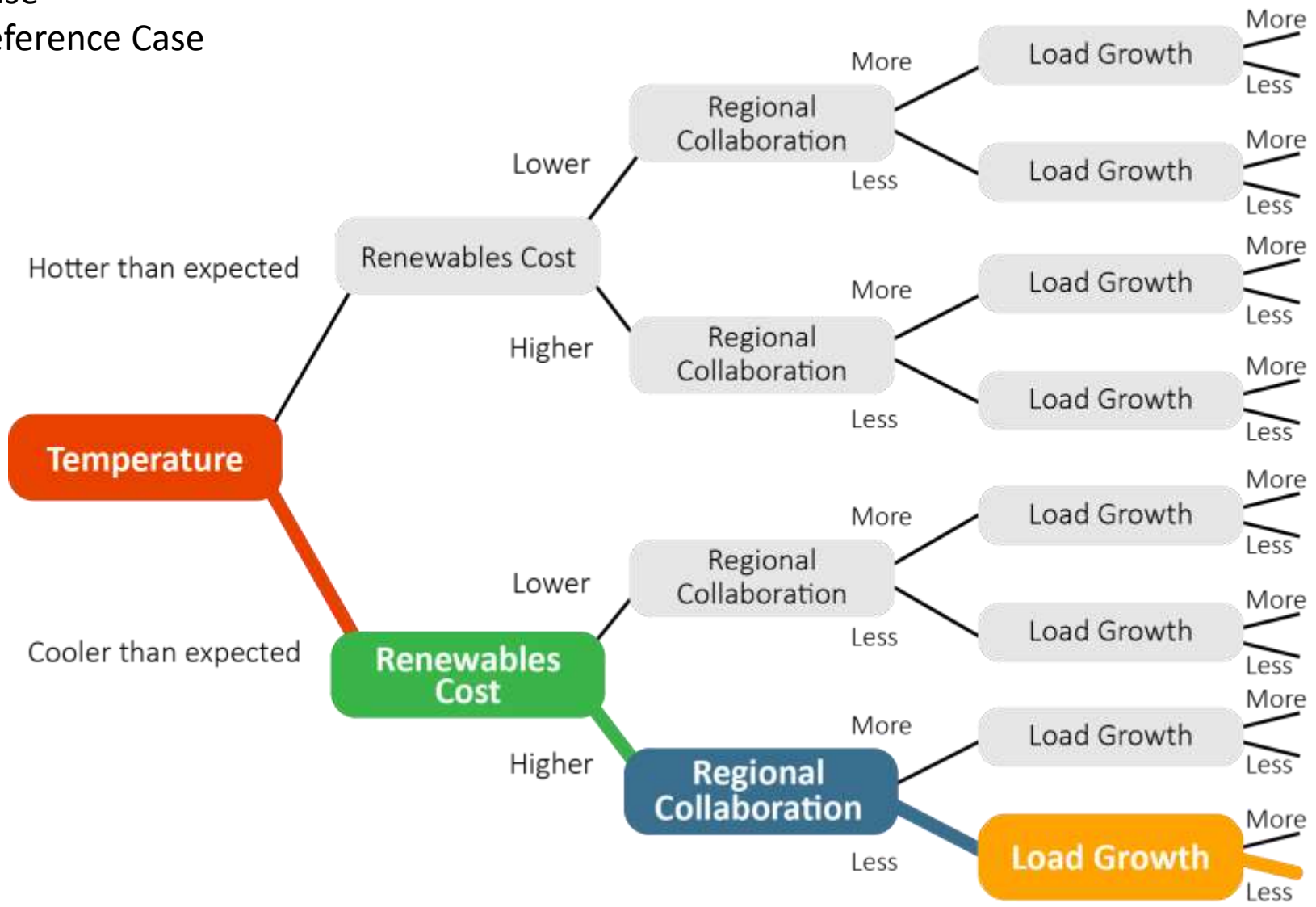
Business as Usual case scenario **2^0F**

Prob. 0.4%
Cost* Reference Case
GHG reduction* Reference Case

It is 2050
Cost of meeting renewable targets are more than expected

A regional RTO has not formed..

Load growth lower than expected.



Probability	$B	GHG MMTons
24.8%	$ 32	3
21.2%	$ 24	(5)
5.1%	$ 37	5
4.3%	$ 27	(4)
4.7%	$ 45	23
4.0%	$ 32	7
1.0%	$ 58	28
0.8%	$ 40	10
12.8%	$ (8)	(7)
10.9%	$ (16)	(15)
2.6%	$ (3)	(5)
2.2%	$ (13)	(14)
2.4%	$ 5	13
2.1%	$ (8)	(3)
0.5%	$ 18	18
0.4%	$ -	-

**Estimated values relative to reference are for illustration only*

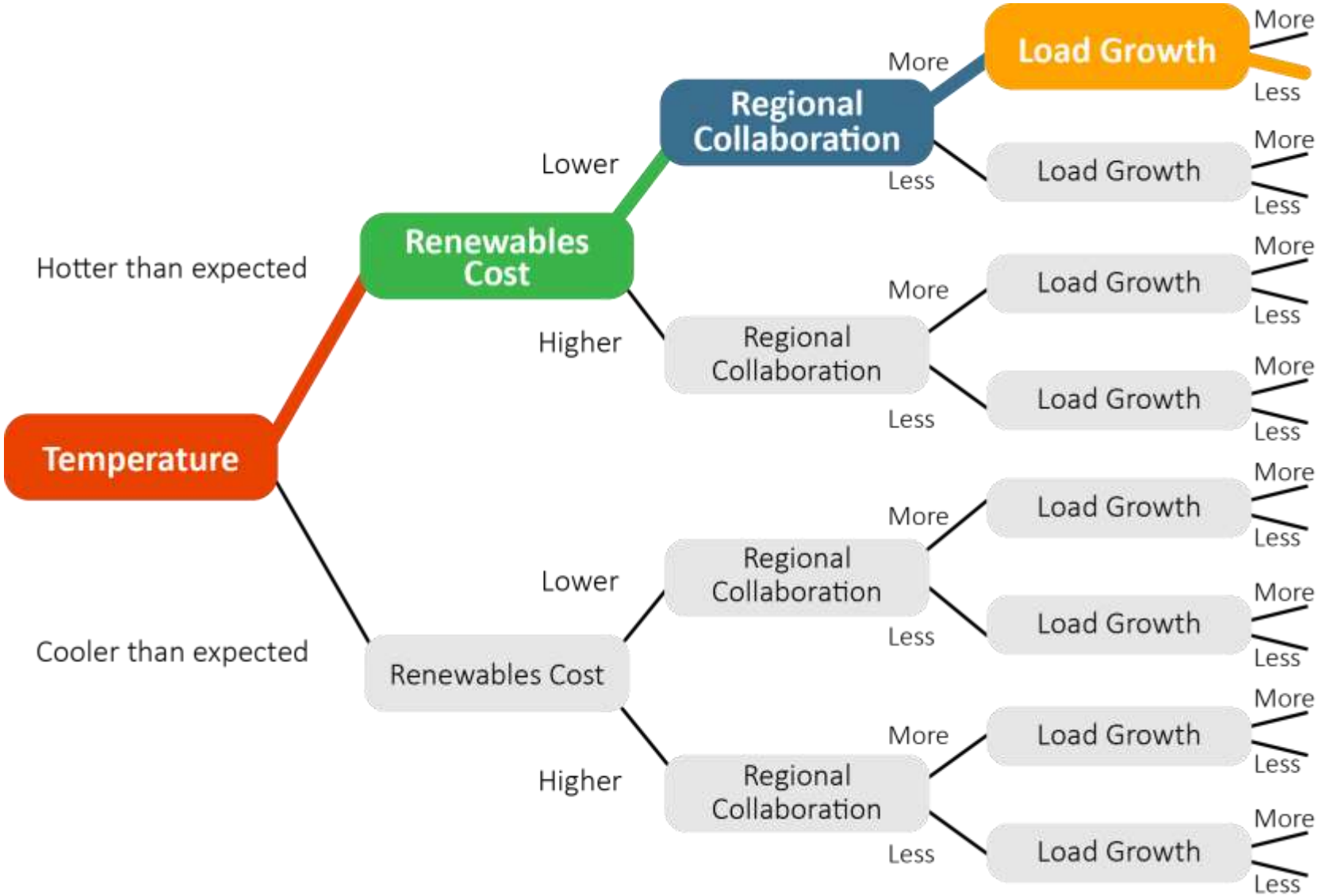
Expected case scenario 4^{0}F

Prob. 21%
Cost* $24 Billion
GHG reduction* 5 MMTons

It is 2050 Renewable targets have been exceeded at lower cost..

A regional RTO has formed..

Load growth lower than expected.



**Estimated values relative to reference are for illustration only*

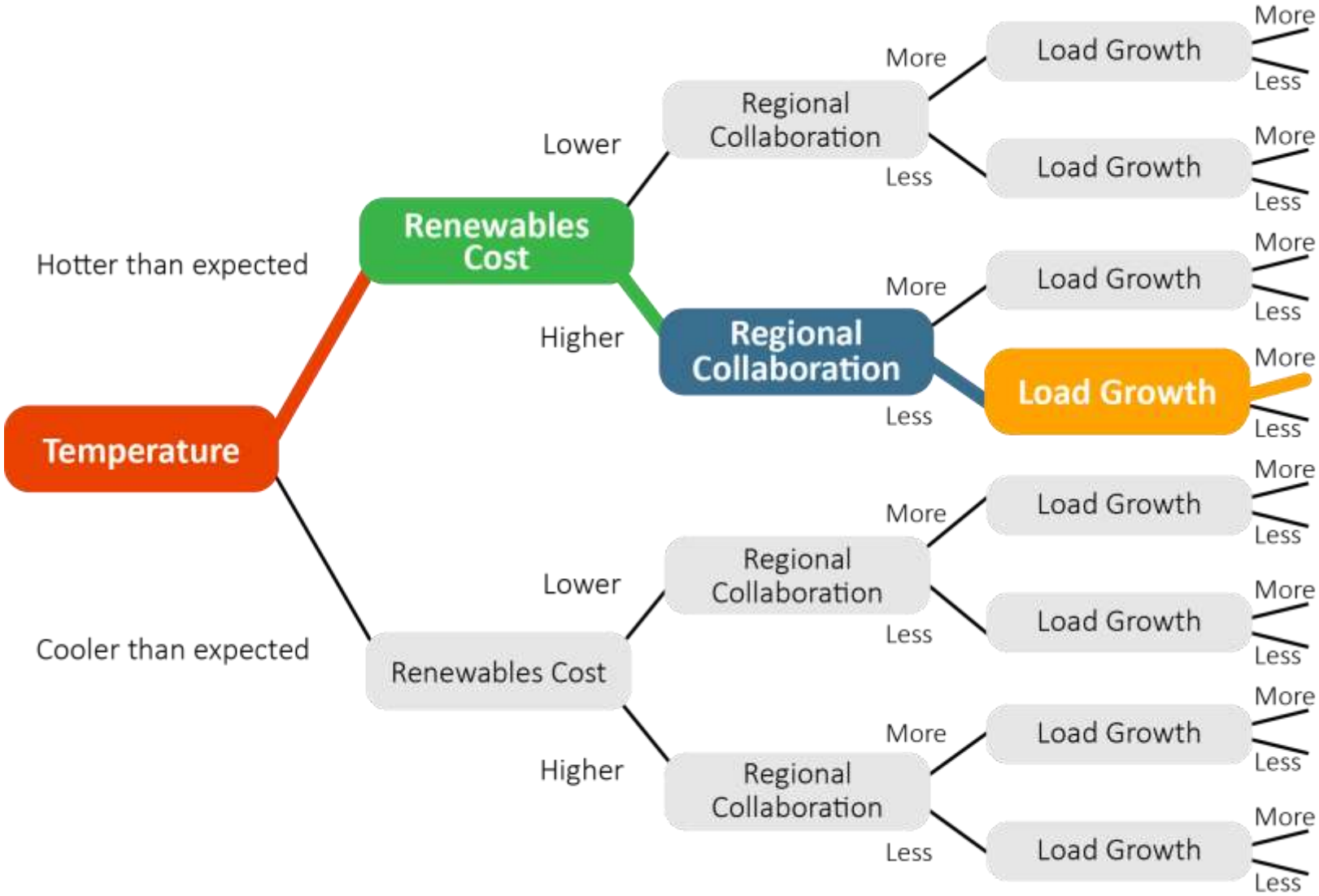
Worst case scenario 4^0F

Prob. 1%
Cost* $58 Billion
GHG increase* 28 MMTons

It is 2050
Cost of meeting renewable targets are more than expected

A regional RTO has not formed..

Load growth higher than expected.



**Estimated values relative to reference are for illustration only*

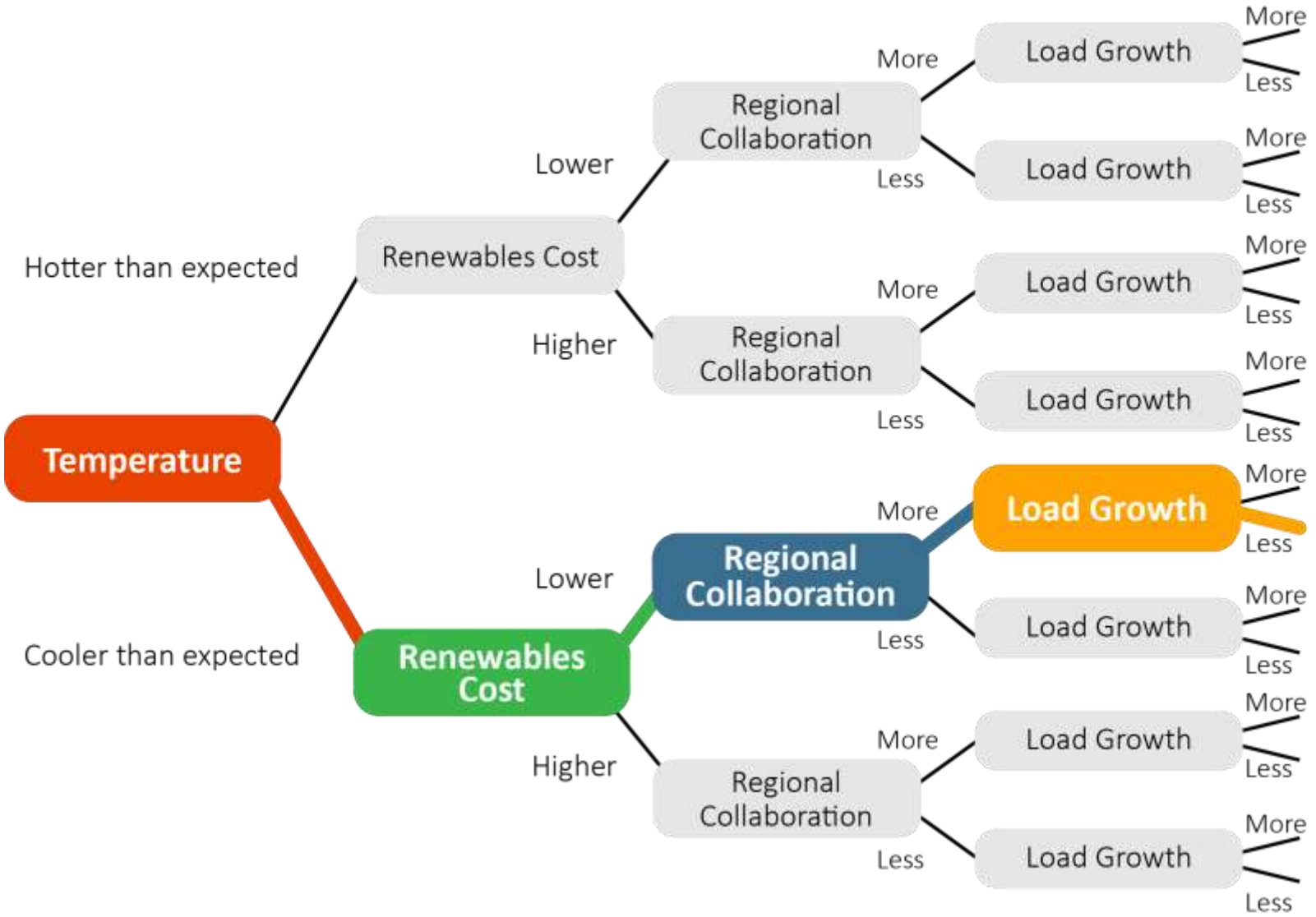
Best case scenario 2^0F

Prob. 11%
Savings* $16 Billion
GHG reduction* 15 MMTons

It is 2050
Renewable targets have been exceeded at lower cost..

A regional RTO has formed..

Load growth lower than expected.



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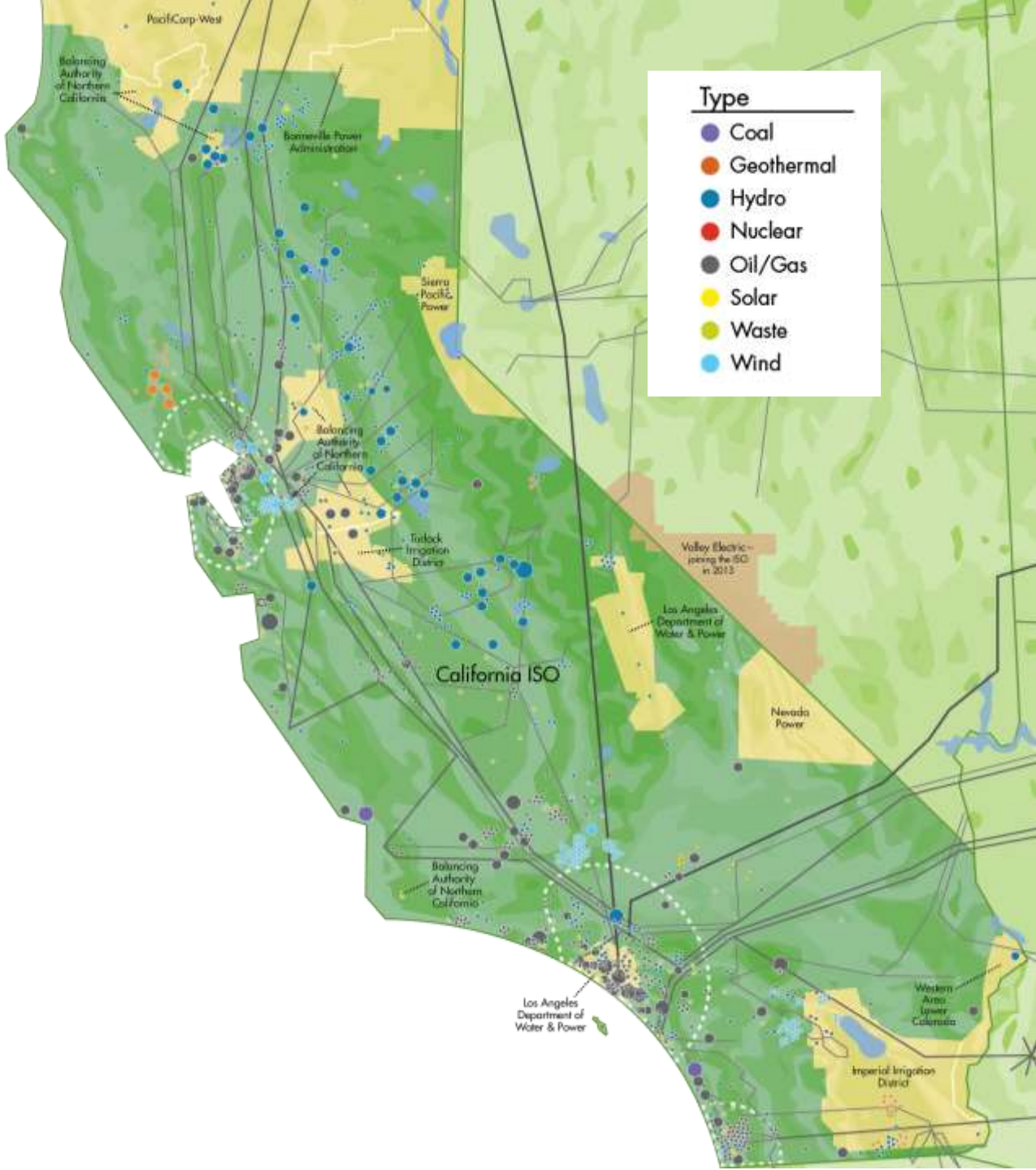
Impact on the Grid

- Sea level rise will compromise coastal grid infrastructure
- Fires will threaten transmission lines
- Higher temperatures will increase demand and decrease supply
- Droughts will impact hydro availability



Drought

Affects availability of Hydro Resources

Critical electric sector infrastructure could also be impacted by flooding

Table 3: Percent exposure of electric assets to 100- and 500-year FEMA flood zones

Electric Assets	FEMA 100-Flood Zone Exposure	500-Year Flood Zone Exposure
Distribution Lines	9%	13%
Distribution Transformers (Pad-Mount)	6%	17%
Transmission Lines	14%	18%
Substations	26%	39%
Power Generation Facilities	0%	0%

Figure 6: PG&E's electric substations identified within the 100-year FEMA flood zone

Source: Pacific Gas & Electric


Wild Fires
are becoming
Fire Storms
Threatening grid infrastructure