



WECC-Wide High Renewable Buildout

Purpose of the High Renewable Case

- Observe effect on wholesale electricity prices in a future where renewable energy is more widely deployed.

Methodology

- Add renewable resources until carbon-free generation is equal to 100% of load.
- Retire WECC coal by 2040.

Outcome

- Portfolio screen for performance in a high renewable energy future.



WECC-Wide High Renewable Buildout



WECC-Wide High Renewable Buildout

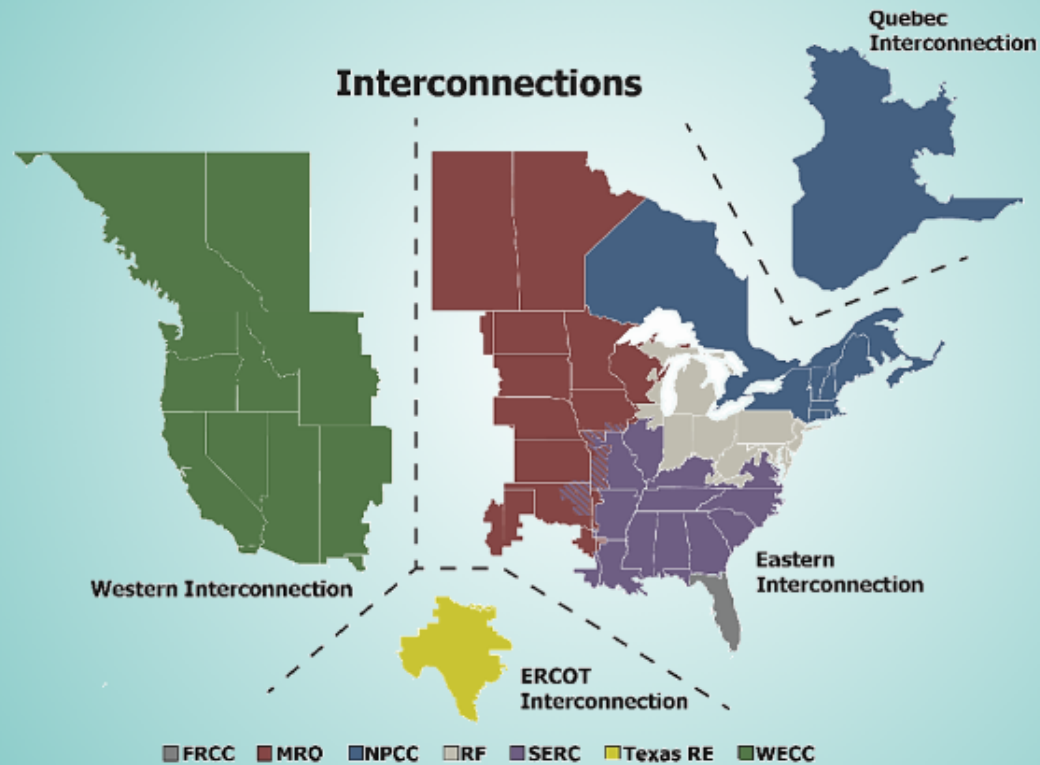
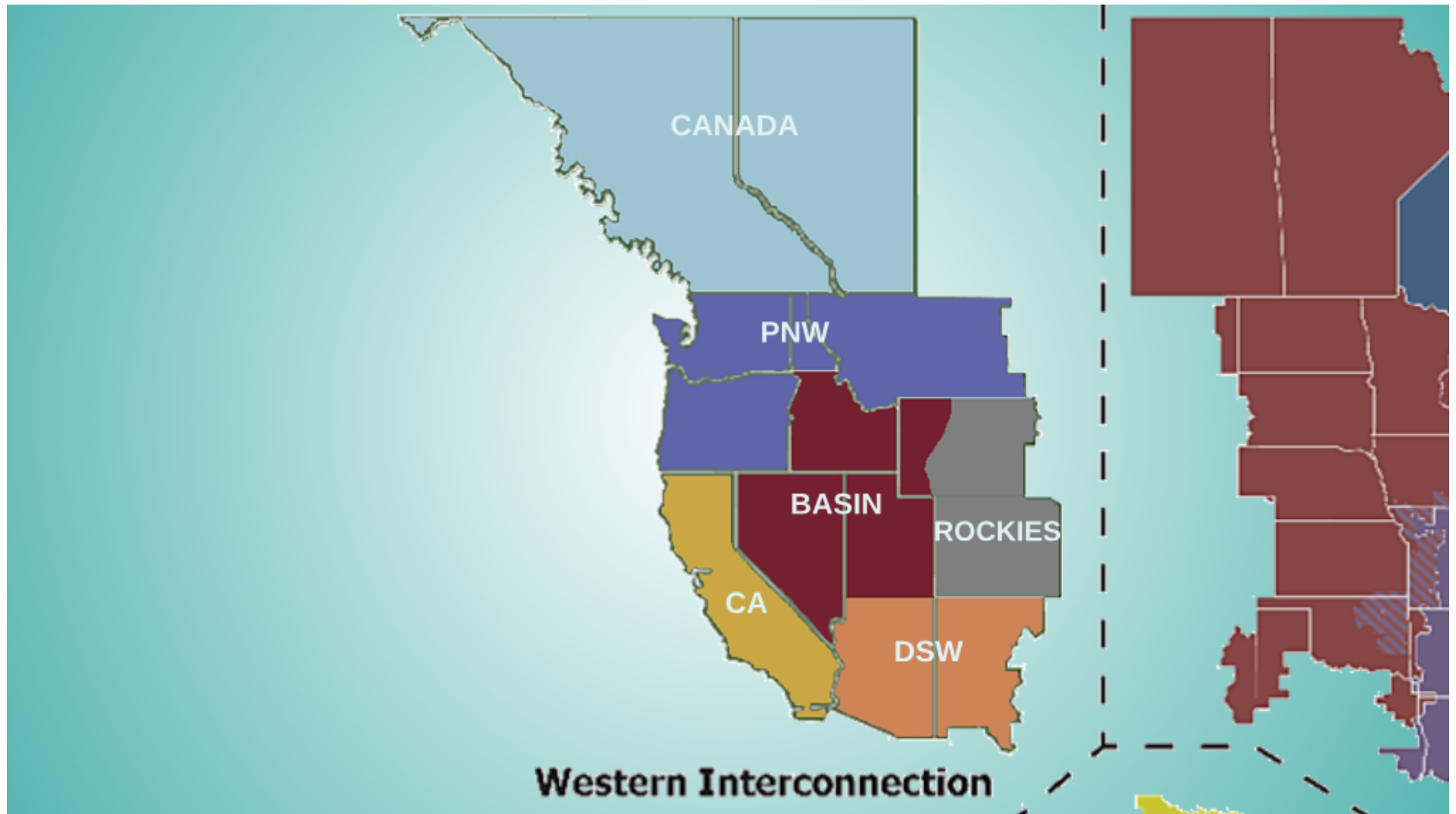
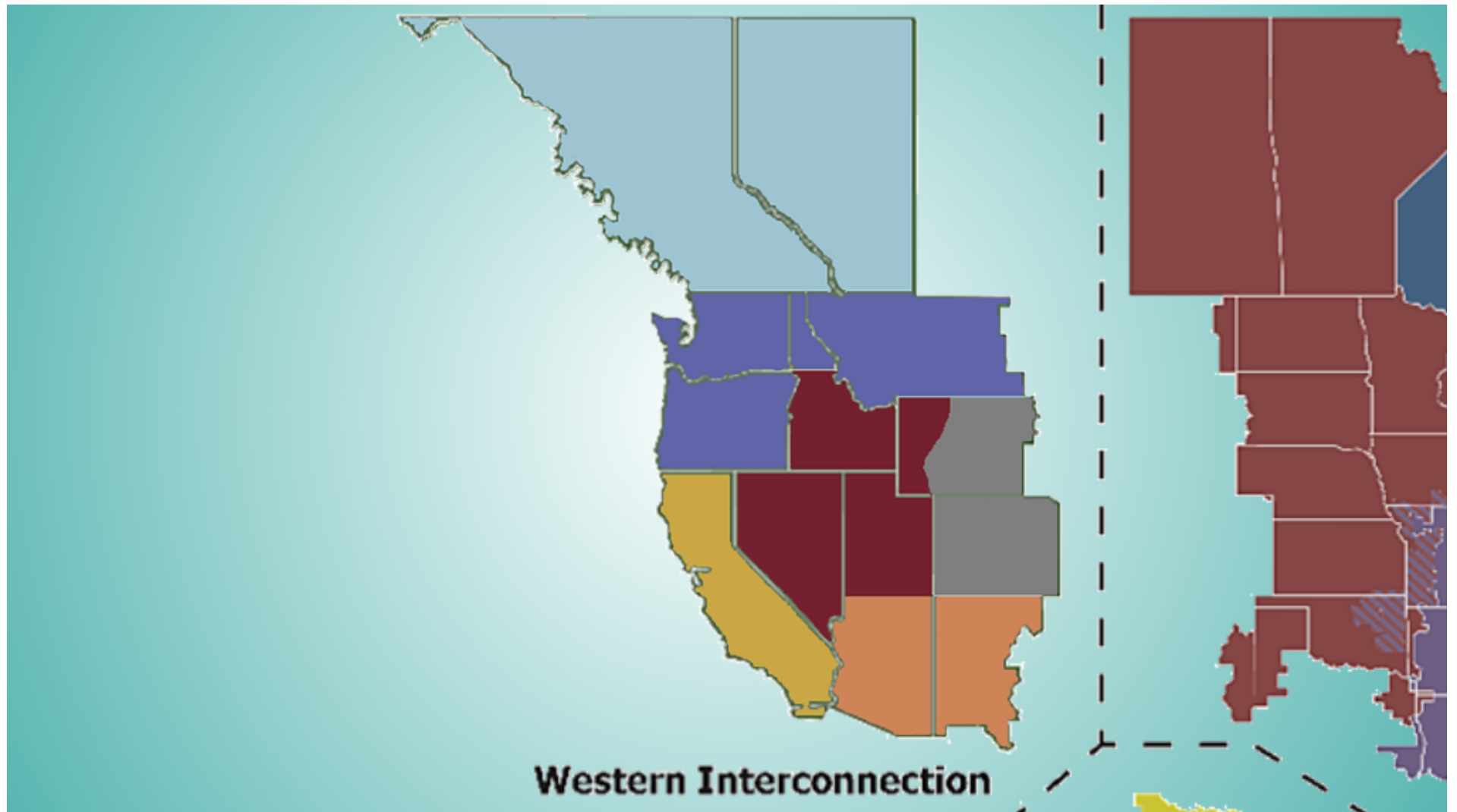
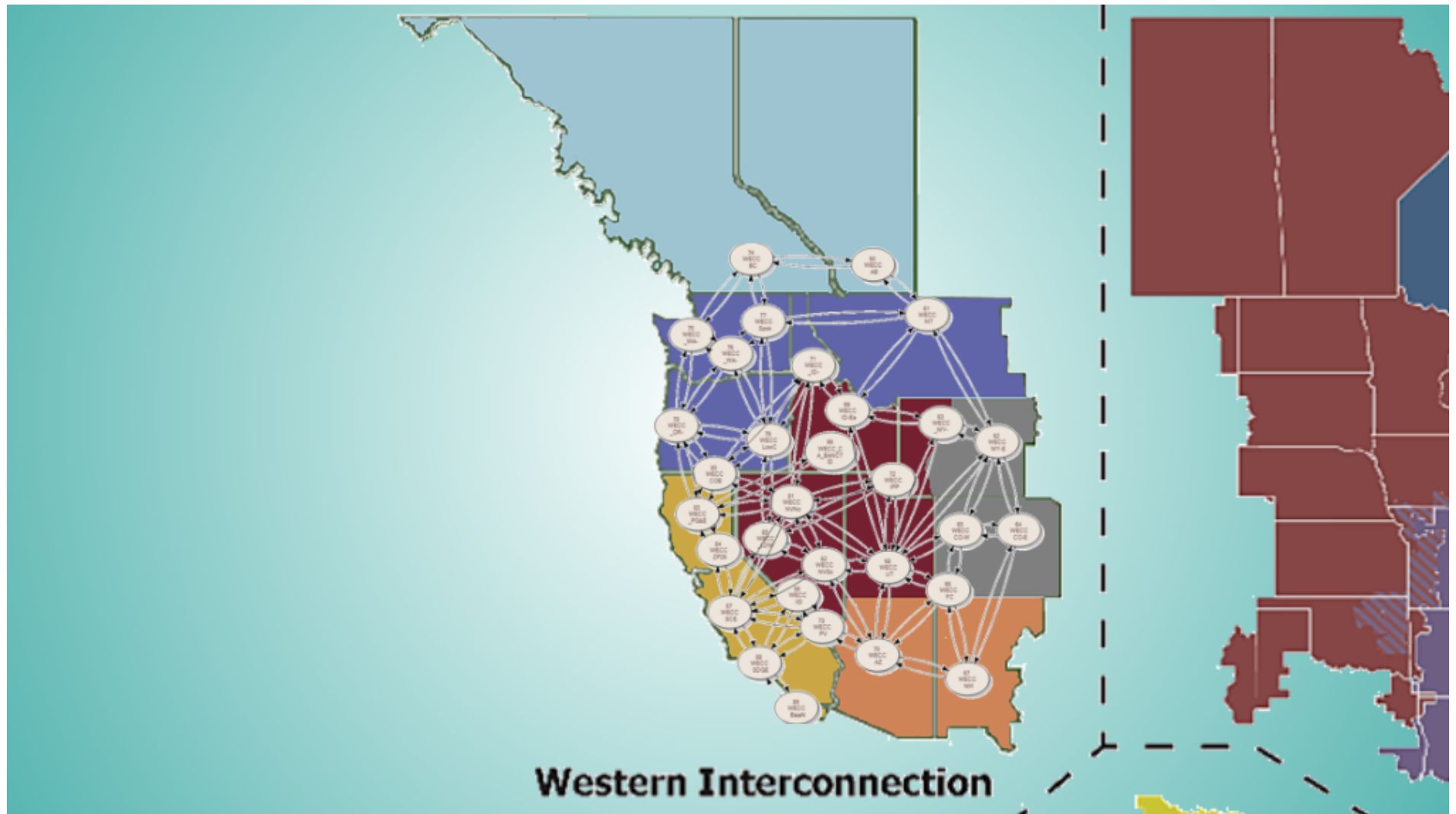


Image: NERC

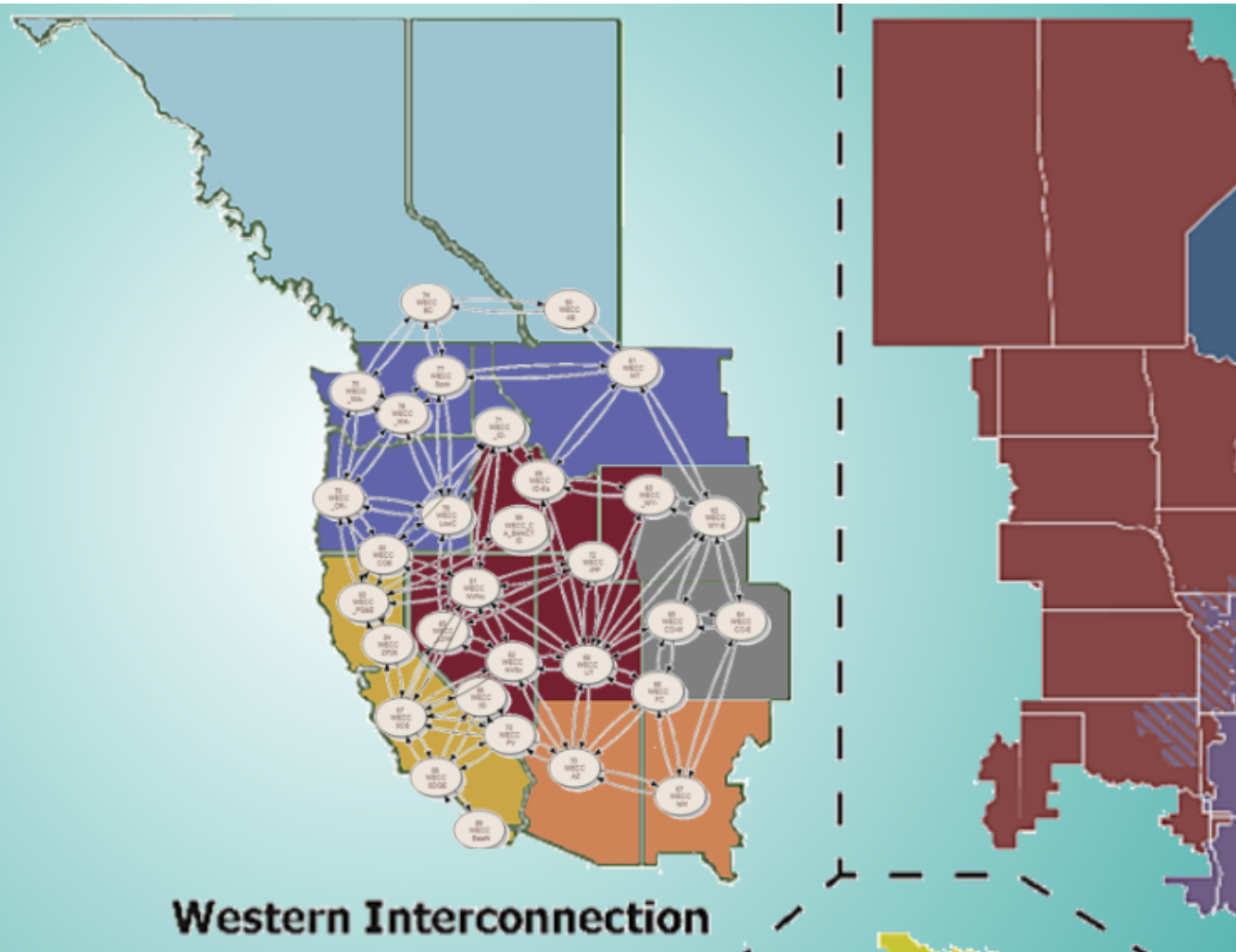






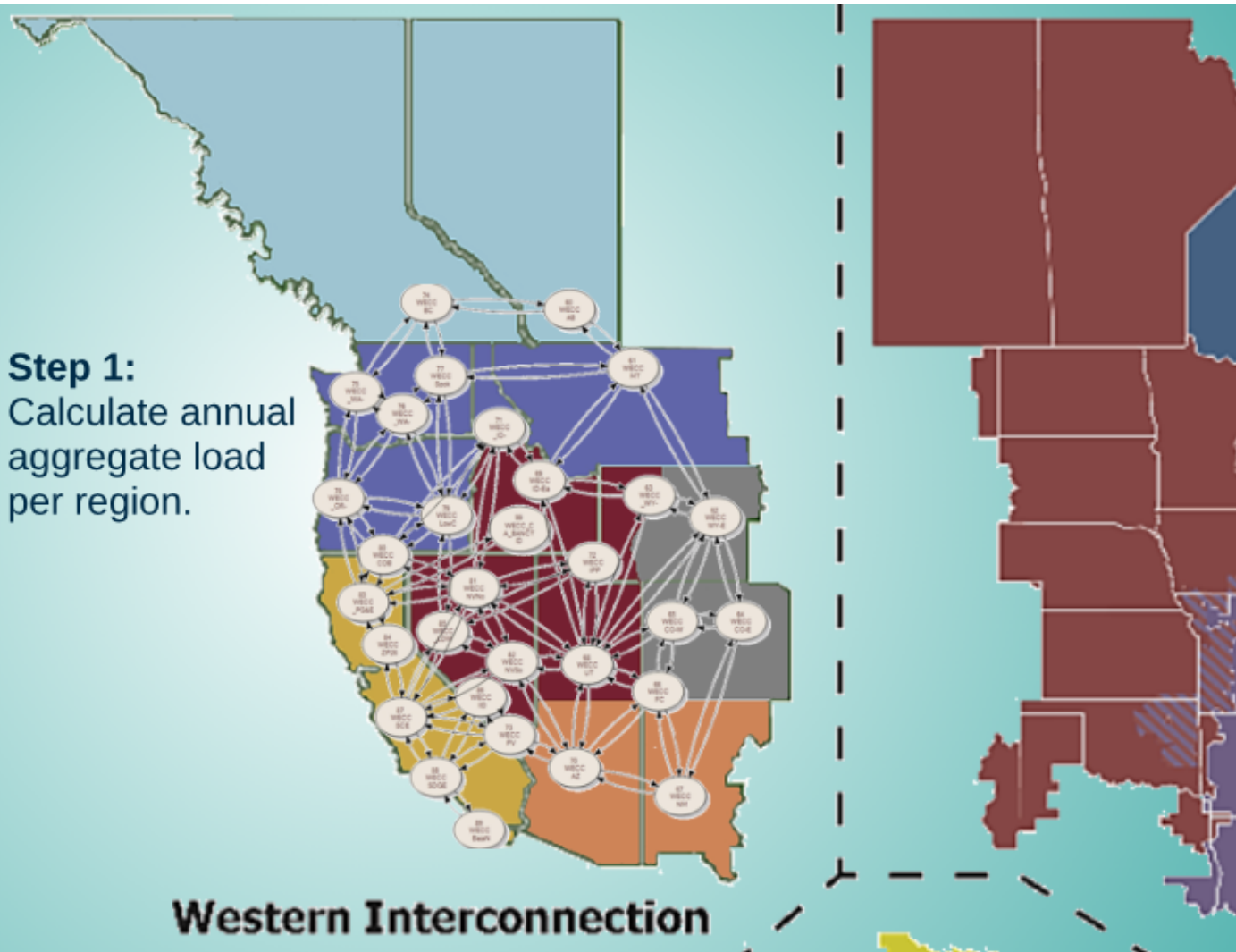


WoodMac Zone	Region
WECC_Alberta	Canada
WECC_BritishColumbia	Canada
WECC_Montana	PNW
WECC_PNW_IdahoSouthwest	PNW
WECC_PNW_LowerColumbia	PNW
WECC_PNW_OregonWest	PNW
WECC_PNW_Spokane	PNW
WECC_PNW_WashingtonCentral	PNW
WECC_PNW_WashingtonWest	PNW
WECC_Colorado East	Rockies
WECC_Colorado West	Rockies
WECC_Wyoming-RMPA	Rockies
WECC_NevadaNorth	Basin
WECC_NevadaSouth	Basin
WECC_PNW_IdahoEast	Basin
WECC_Utah	Basin
WECC_Wyoming-NWPP	Basin
WECC_BajaNorth	California
WECC_CA_BANCTID	California
WECC_CA_IID	California
WECC_CA_LADWP	California
WECC_CA_PGandE_North	California
WECC_CA_PGandE_ZP26	California
WECC_CA_SCE	California
WECC_CA_SDGE	California
WECC_COB	California
WECC_IPP	California
WECC_Arizona	DSW
WECC_FourCorners	DSW
WECC_NewMexico	DSW
WECC_Palo Verde	DSW

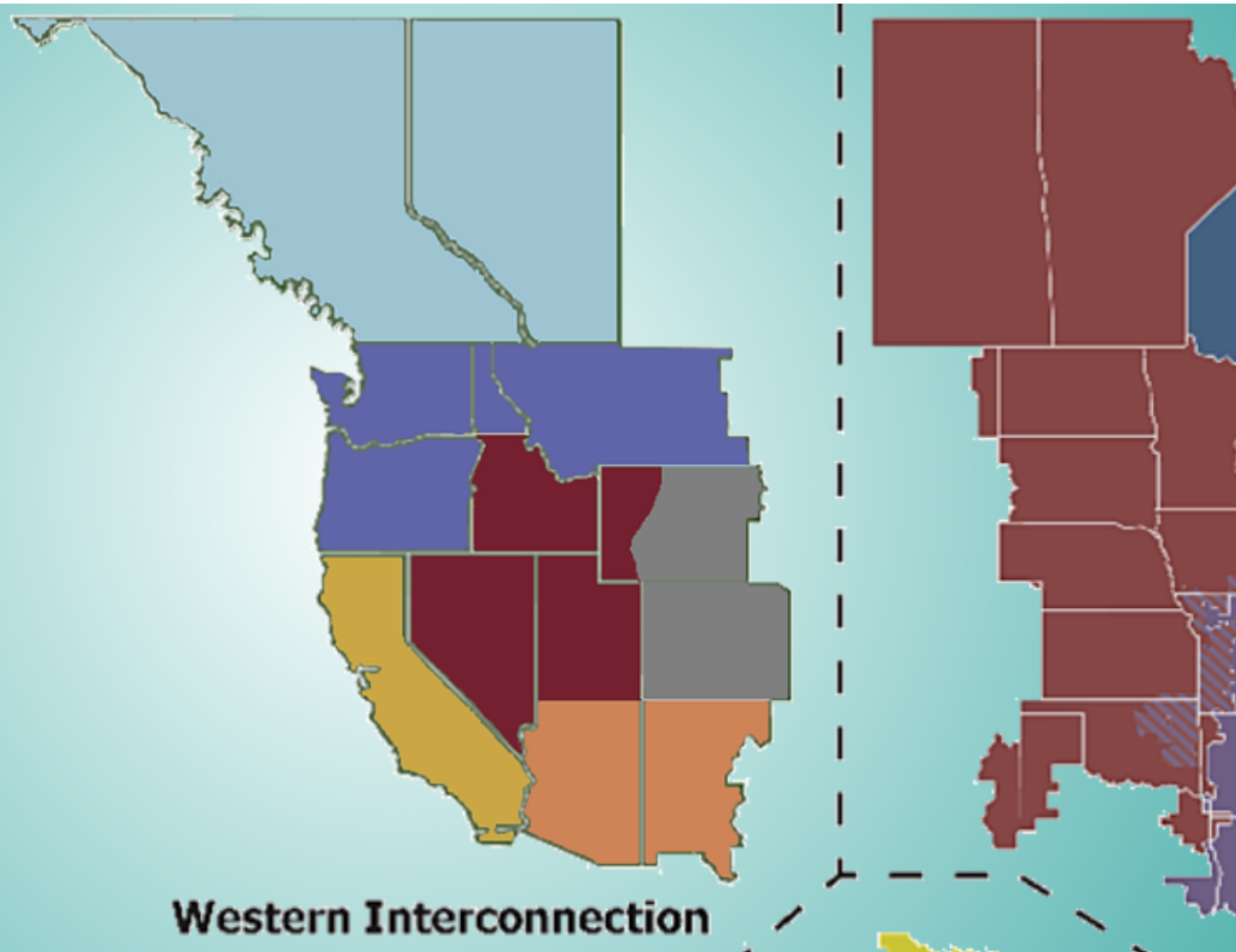


WoodMac Zone	Region
WECC_Alberta	Canada
WECC_BritishColumbia	Canada
WECC_Montana	PNW
WECC_PNW_IdahoSouthwest	PNW
WECC_PNW_LowerColumbia	PNW
WECC_PNW_OregonWest	PNW
WECC_PNW_Spokane	PNW
WECC_PNW_WashingtonCentral	PNW
WECC_PNW_WashingtonWest	PNW
WECC_Colorado East	Rockies
WECC_Colorado West	Rockies
WECC_Wyoming-RMPA	Rockies
WECC_NevadaNorth	Basin
WECC_NevadaSouth	Basin
WECC_PNW_IdahoEast	Basin
WECC_Utah	Basin
WECC_Wyoming-NWPP	Basin
WECC_BajaNorth	California
WECC_CA_BANCTID	California
WECC_CA_IID	California
WECC_CA_LADWP	California
WECC_CA_PGandE_North	California
WECC_CA_PGandE_ZP26	California
WECC_CA_SCE	California
WECC_CA_SDGE	California
WECC_COB	California
WECC_IPP	California
WECC_Arizona	DSW
WECC_FourCorners	DSW
WECC_NewMexico	DSW
WECC_Palo Verde	DSW

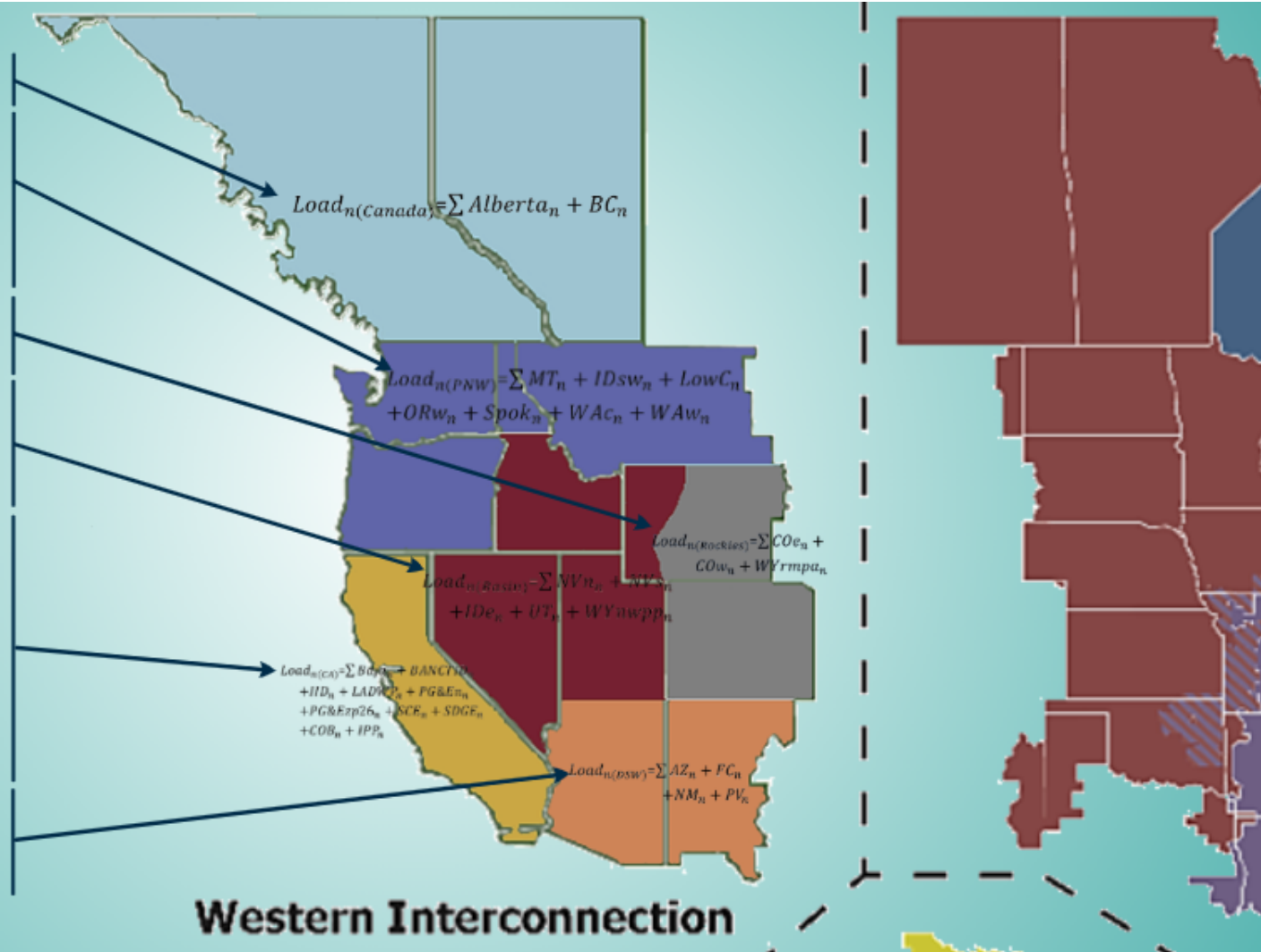
Step 1:
Calculate annual
aggregate load
per region.

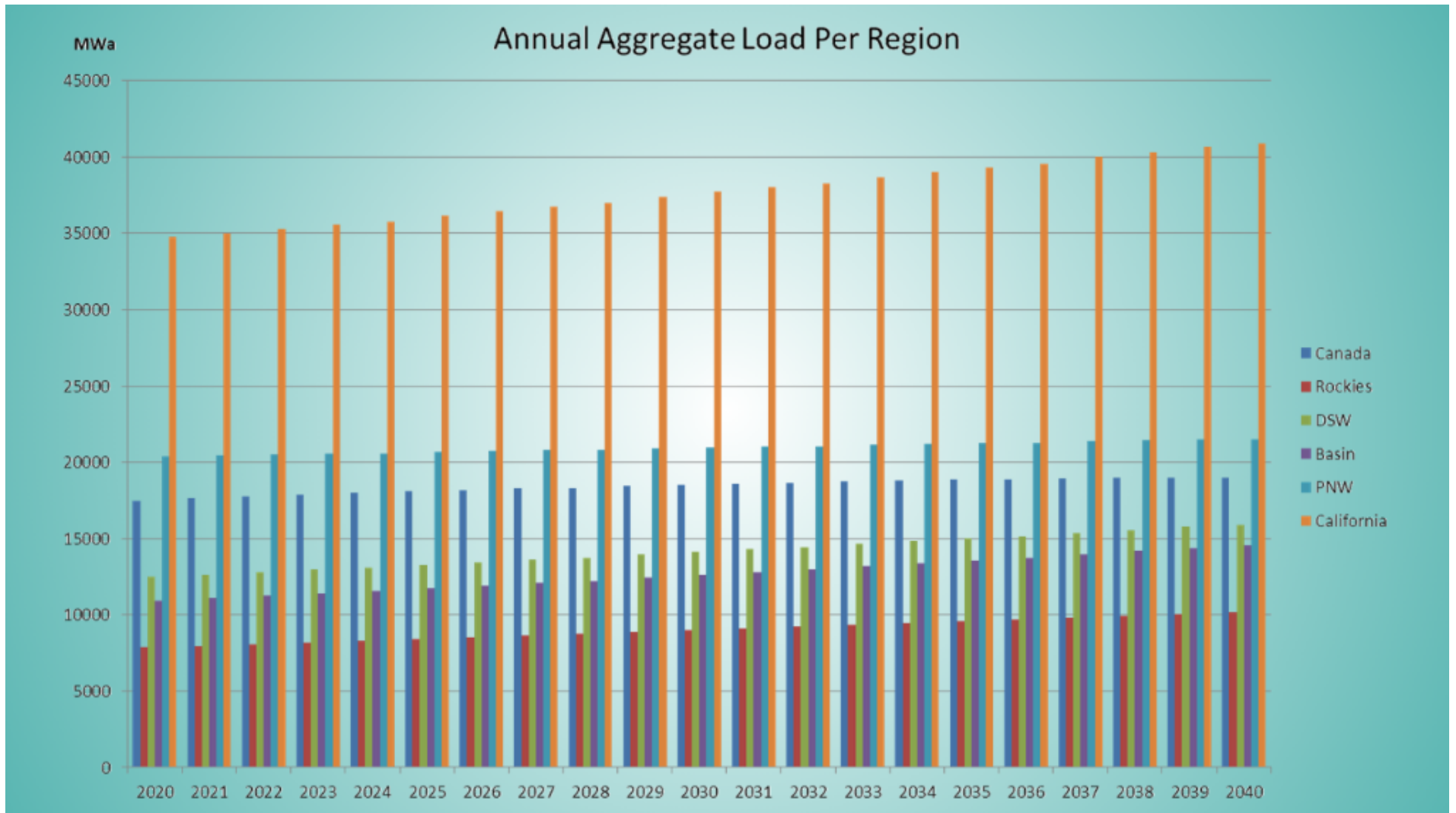


WoodMac Zone	Region
WECC_Alberta	Canada
WECC_BritishColumbia	Canada
WECC_Montana	PNW
WECC_PNW_IdahoSouthwest	PNW
WECC_PNW_LowerColumbia	PNW
WECC_PNW_OregonWest	PNW
WECC_PNW_Spokane	PNW
WECC_PNW_WashingtonCentral	PNW
WECC_PNW_WashingtonWest	PNW
WECC_Colorado East	Rockies
WECC_Colorado West	Rockies
WECC_Wyoming-RMPA	Rockies
WECC_NevadaNorth	Basin
WECC_NevadaSouth	Basin
WECC_PNW_IdahoEast	Basin
WECC_Utah	Basin
WECC_Wyoming-NWPP	Basin
WECC_BajaNorth	California
WECC_CA_BANCTID	California
WECC_CA_IID	California
WECC_CA_LADWP	California
WECC_CA_PGandE_North	California
WECC_CA_PGandE_ZP26	California
WECC_CA_SCE	California
WECC_CA_SDGE	California
WECC_COB	California
WECC_IPP	California
WECC_Arizona	DSW
WECC_FourCorners	DSW
WECC_NewMexico	DSW
WECC_Palo Verde	DSW



WoodMac Zone	Region
WECC_Alberta	Canada
WECC_BritishColumbia	Canada
WECC_Montana	PNW
WECC_PNW_IdahoSouthwest	PNW
WECC_PNW_LowerColumbia	PNW
WECC_PNW_OregonWest	PNW
WECC_PNW_Spokane	PNW
WECC_PNW_WashingtonCentral	PNW
WECC_PNW_WashingtonWest	PNW
WECC_Colorado East	Rockies
WECC_Colorado West	Rockies
WECC_Wyoming-RMPA	Rockies
WECC_NevadaNorth	Basin
WECC_NevadaSouth	Basin
WECC_PNW_IdahoEast	Basin
WECC_Utah	Basin
WECC_Wyoming-NWPP	Basin
WECC_BajaNorth	California
WECC_CA_BANCTID	California
WECC_CA_IID	California
WECC_CA_LADWP	California
WECC_CA_PGandE_North	California
WECC_CA_PGandE_ZP26	California
WECC_CA_SCE	California
WECC_CA_SDGE	California
WECC_COB	California
WECC_IPP	California
WECC_Arizona	DSW
WECC_FourCorners	DSW
WECC_NewMexico	DSW
WECC_Palo Verde	DSW

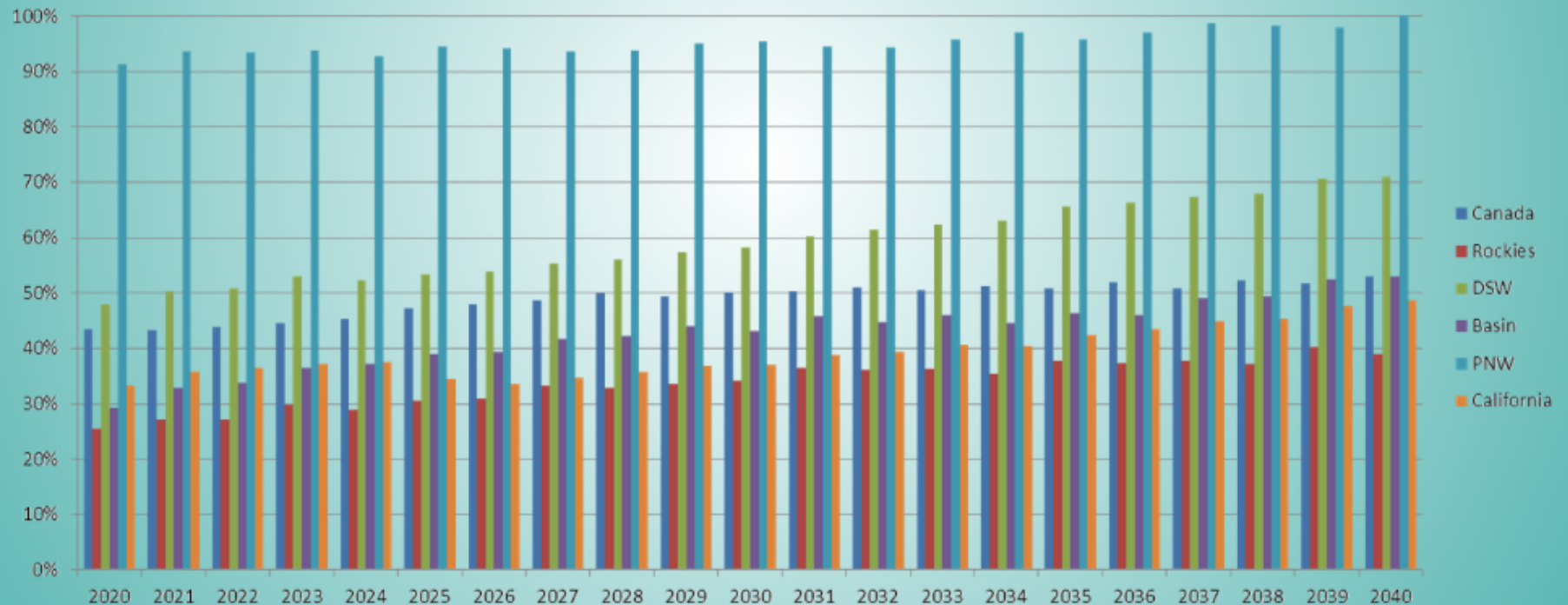






Step 2: Calculate annual regional renewable energy percent, specified by WoodMackenzie.

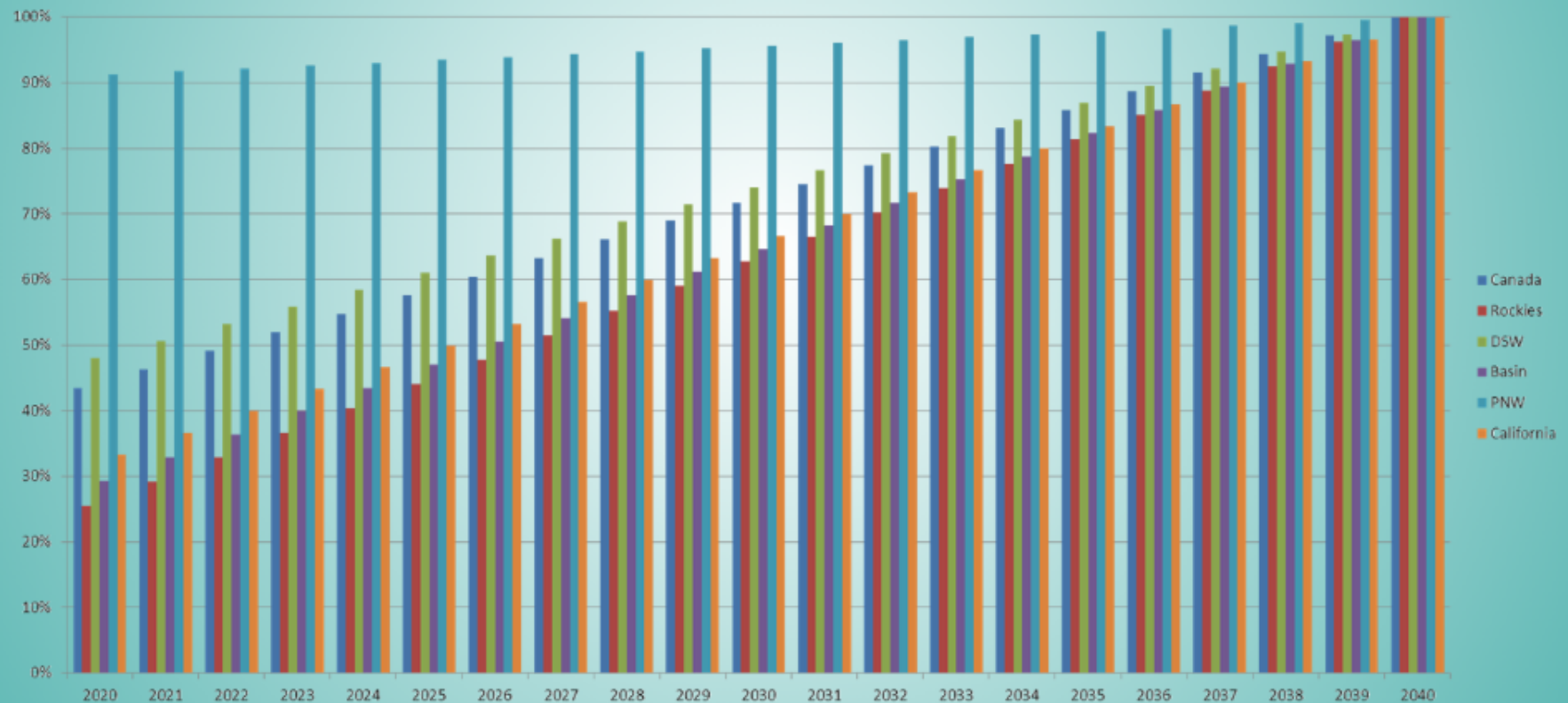
Trajectory - WoodMackenzie % of Load Served by Carbon-Free Resources



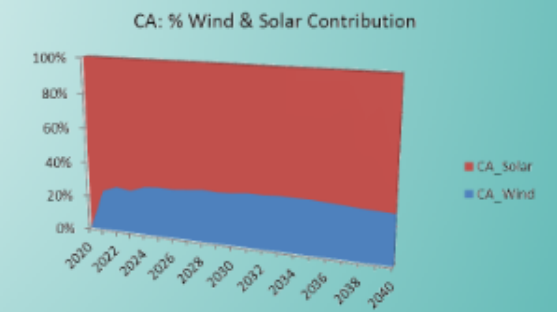
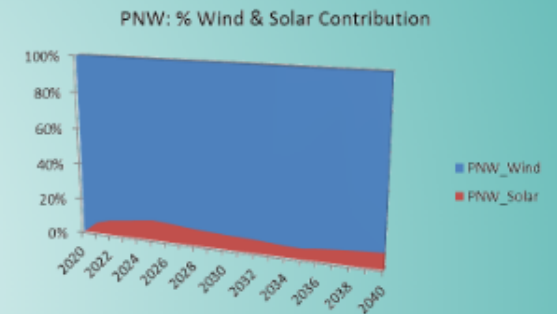
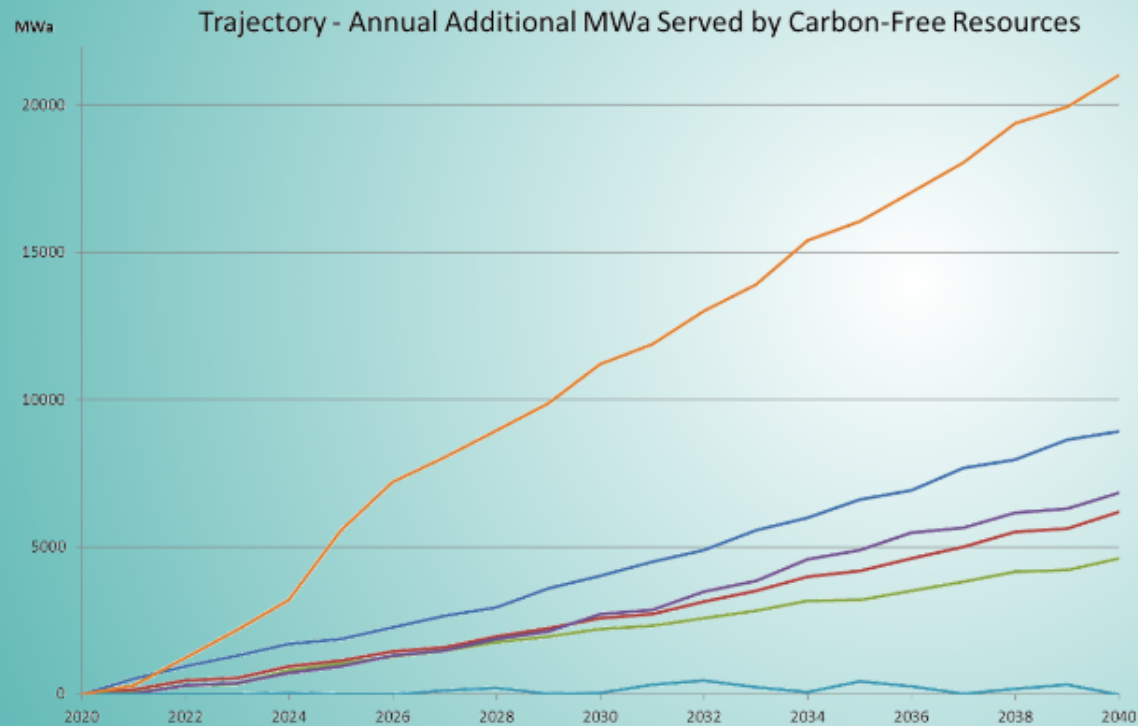


Step 3: Apply linear interpolation to project growth of renewables from 2020 through 2040 with goal of carbon-free generation capability equal to load by region in 2040.

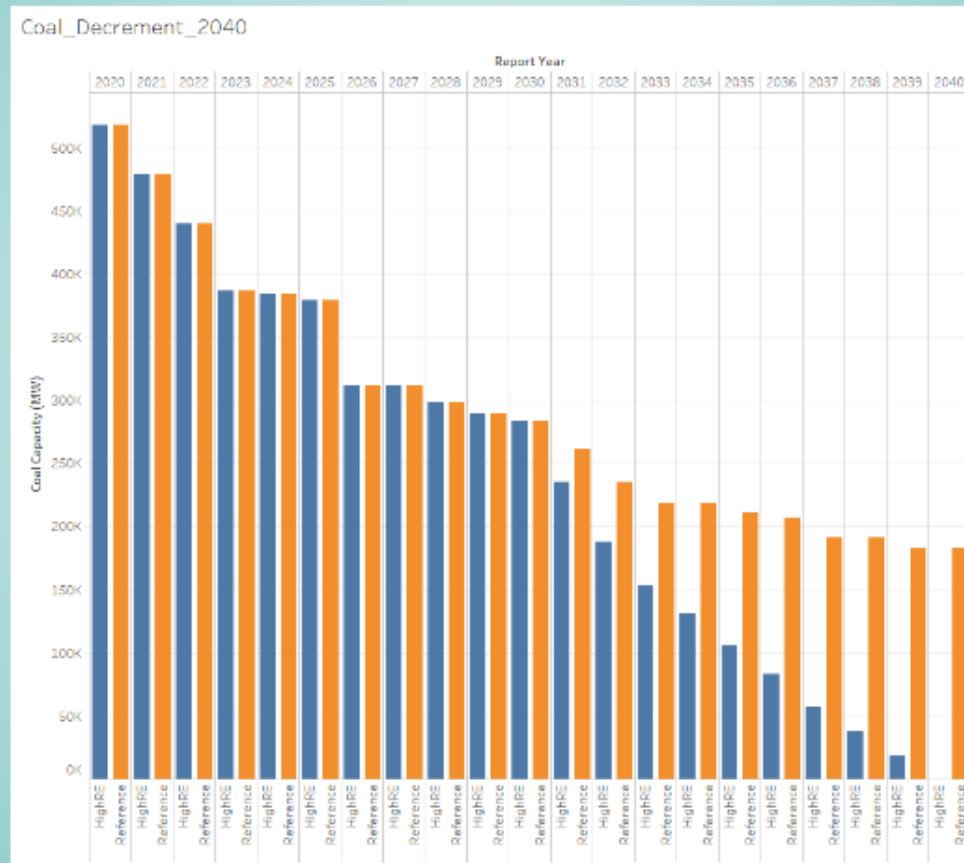
Trajectory - High Renewable % of Load Served by Carbon-Free Resources



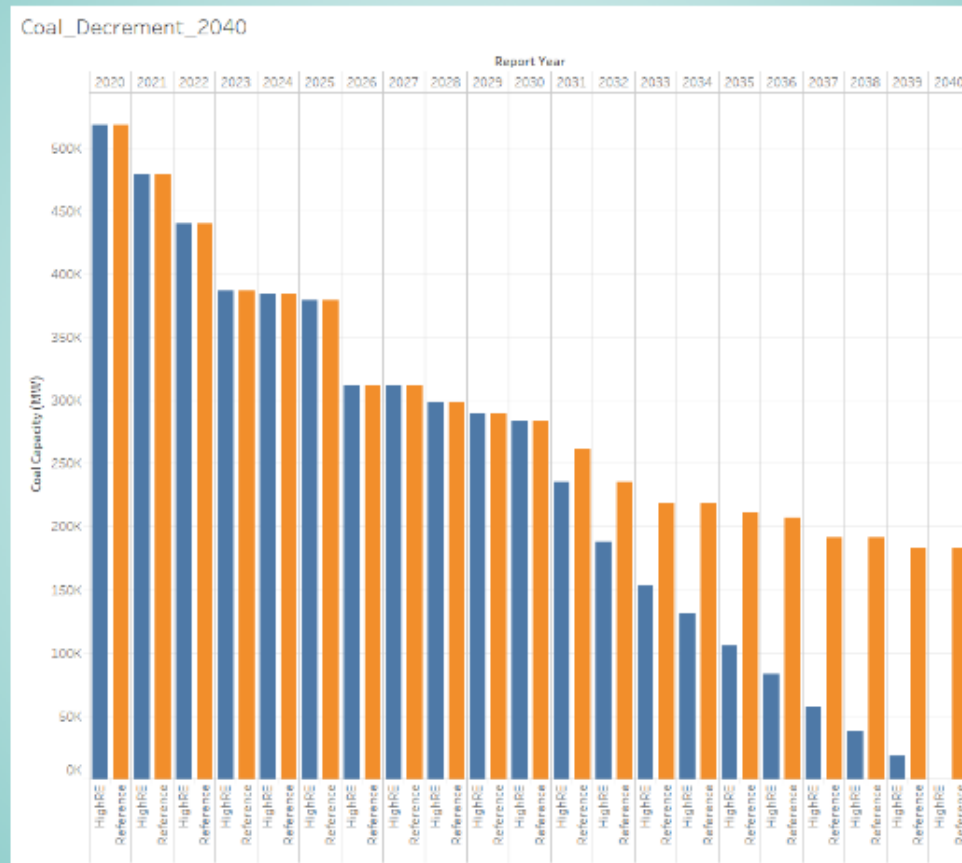
Step 4: Split percent between solar and wind annually per region, specified by WoodMackenzie, and apply annual wind and solar factors to renewable growth per region.



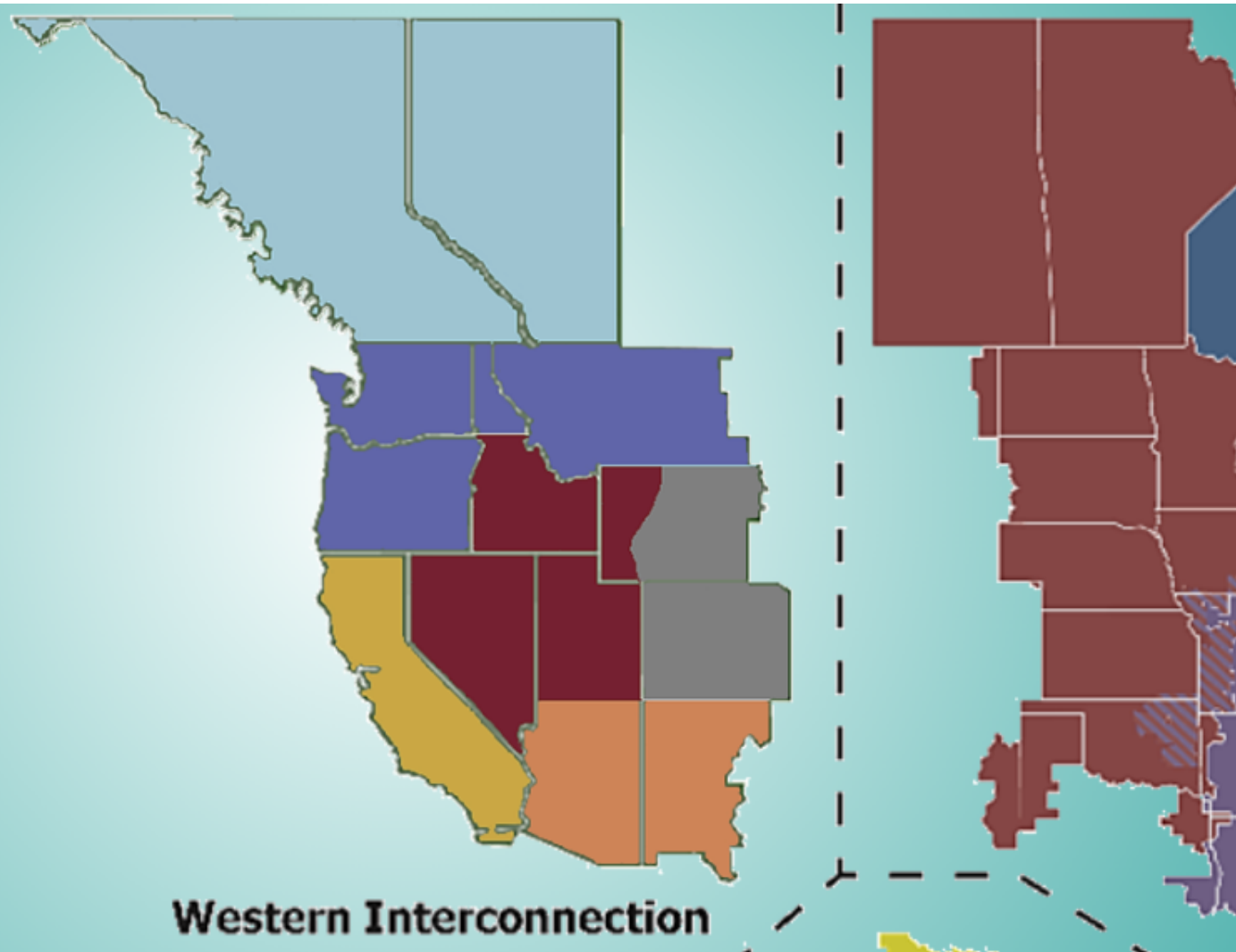
Step 5: Reduce WECC coal resources to zero over the 2030-2040 timespan.



Step 5: Reduce WECC coal resources to zero over the 2030-2040 timespan.

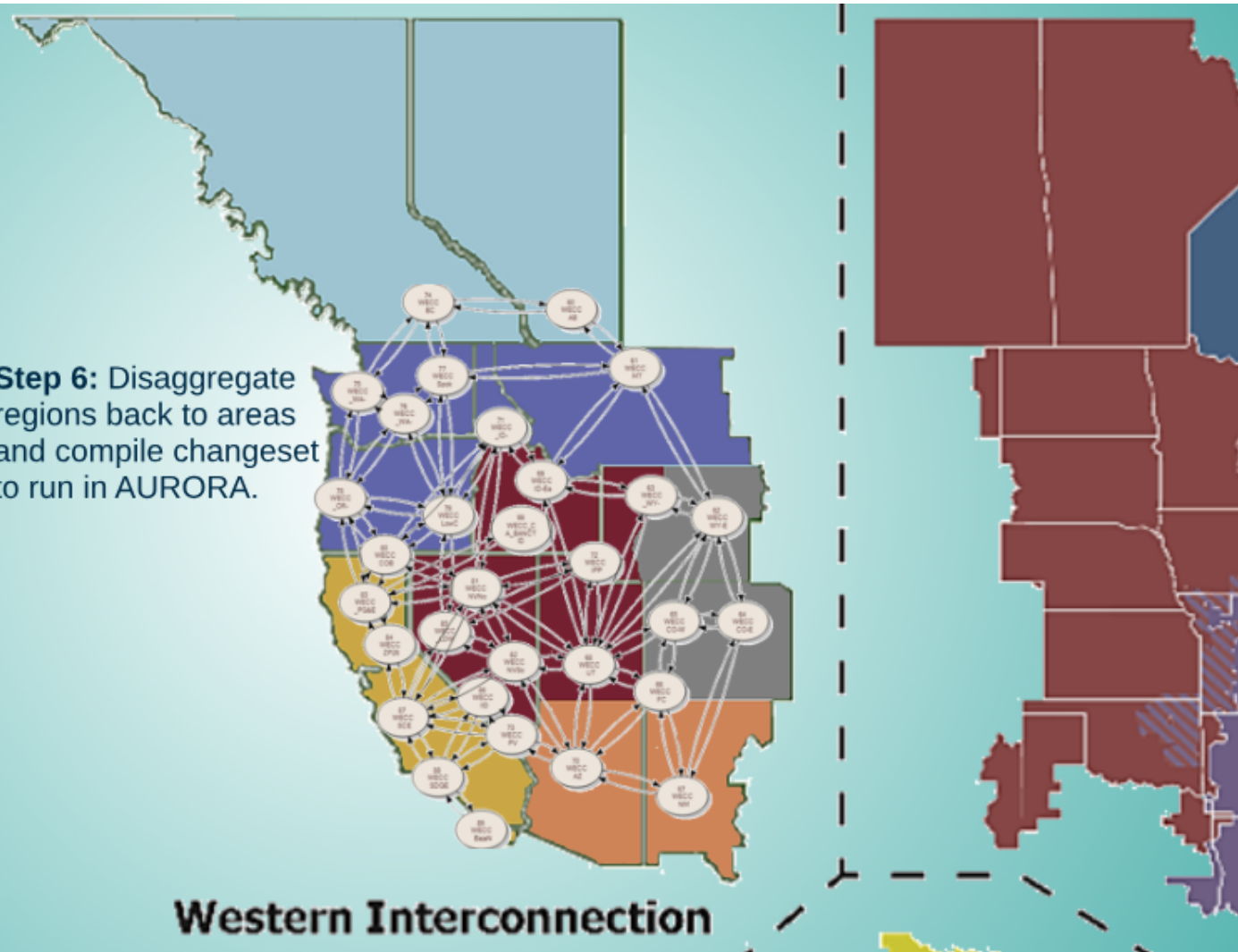


WoodMac Zone	Region
WECC_Alberta	Canada
WECC_BritishColumbia	Canada
WECC_Montana	PNW
WECC_PNW_IdahoSouthwest	PNW
WECC_PNW_LowerColumbia	PNW
WECC_PNW_OregonWest	PNW
WECC_PNW_Spokane	PNW
WECC_PNW_WashingtonCentral	PNW
WECC_PNW_WashingtonWest	PNW
WECC_Colorado East	Rockies
WECC_Colorado West	Rockies
WECC_Wyoming-RMPA	Rockies
WECC_NevadaNorth	Basin
WECC_NevadaSouth	Basin
WECC_PNW_IdahoEast	Basin
WECC_Utah	Basin
WECC_Wyoming-NWPP	Basin
WECC_BajaNorth	California
WECC_CA_BANCTID	California
WECC_CA_IID	California
WECC_CA_LADWP	California
WECC_CA_PGandE_North	California
WECC_CA_PGandE_ZP26	California
WECC_CA_SCE	California
WECC_CA_SDGE	California
WECC_COB	California
WECC_IPP	California
WECC_Arizona	DSW
WECC_FourCorners	DSW
WECC_NewMexico	DSW
WECC_Palo Verde	DSW



WoodMac Zone	Region
WECC_Alberta	Canada
WECC_BritishColumbia	Canada
WECC_Montana	PNW
WECC_PNW_IdahoSouthwest	PNW
WECC_PNW_LowerColumbia	PNW
WECC_PNW_OregonWest	PNW
WECC_PNW_Spokane	PNW
WECC_PNW_WashingtonCentral	PNW
WECC_PNW_WashingtonWest	PNW
WECC_Colorado East	Rockies
WECC_Colorado West	Rockies
WECC_Wyoming-RMPA	Rockies
WECC_NevadaNorth	Basin
WECC_NevadaSouth	Basin
WECC_PNW_IdahoEast	Basin
WECC_Utah	Basin
WECC_Wyoming-NWPP	Basin
WECC_BajaNorth	California
WECC_CA_BANCTID	California
WECC_CA_IID	California
WECC_CA_LADWP	California
WECC_CA_PGandE_North	California
WECC_CA_PGandE_ZP26	California
WECC_CA_SCE	California
WECC_CA_SDGE	California
WECC_COB	California
WECC_IPP	California
WECC_Arizona	DSW
WECC_FourCorners	DSW
WECC_NewMexico	DSW
WECC_Palo Verde	DSW

Step 6: Disaggregate regions back to areas and compile changeset to run in AURORA.

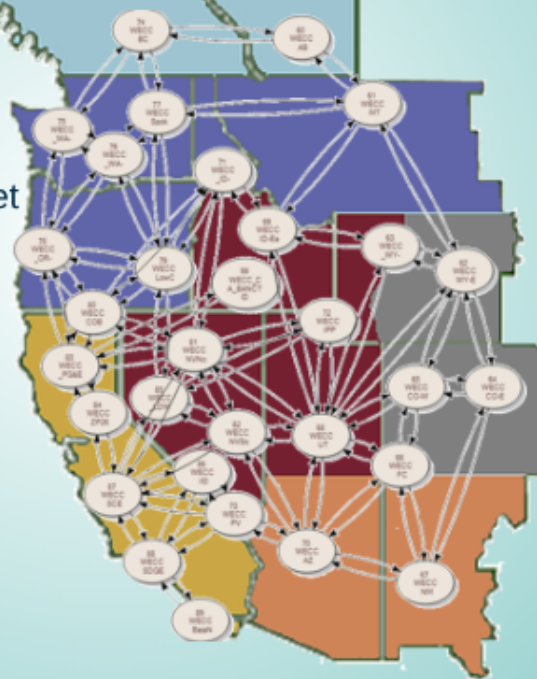


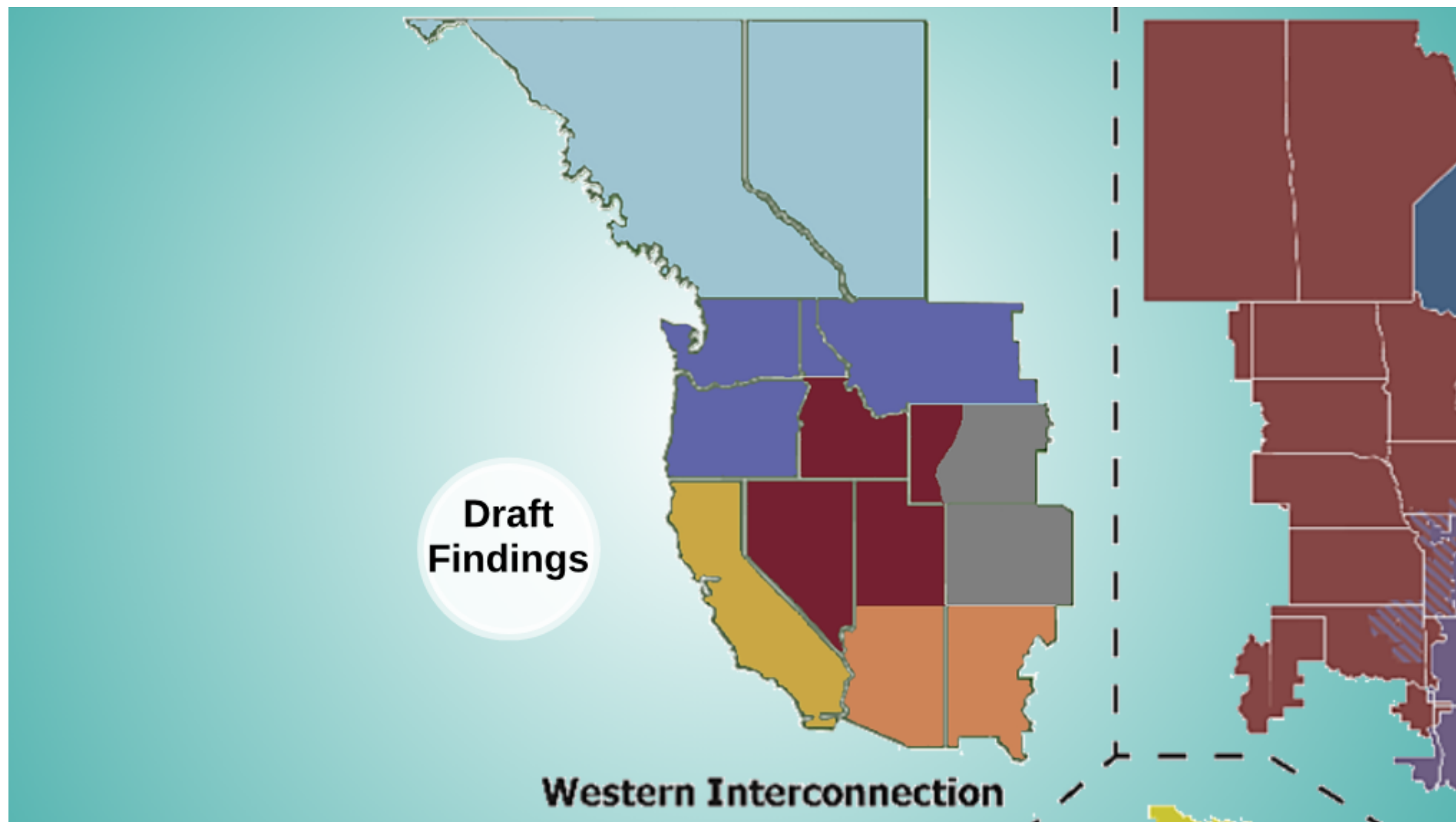
WoodMac Zone	Region
WECC_Alberta	Canada
WECC_BritishColumbia	Canada
WECC_Montana	PNW
WECC_PNW_IdahoSouthwest	PNW
WECC_PNW_LowerColumbia	PNW
WECC_PNW_OregonWest	PNW
WECC_PNW_Spokane	PNW
WECC_PNW_WashingtonCentral	PNW
WECC_PNW_WashingtonWest	PNW
WECC_Colorado East	Rockies
WECC_Colorado West	Rockies
WECC_Wyoming-RMPA	Rockies
WECC_NevadaNorth	Basin
WECC_NevadaSouth	Basin
WECC_PNW_IdahoEast	Basin
WECC_Utah	Basin
WECC_Wyoming-NWPP	Basin
WECC_BajaNorth	California
WECC_CA_BANCTID	California
WECC_CA_IID	California
WECC_CA_LADWP	California
WECC_CA_PGandE_North	California
WECC_CA_PGandE_ZP26	California
WECC_CA_SCE	California
WECC_CA_SDGE	California
WECC_COB	California
WECC_IPP	California
WECC_Arizona	DSW
WECC_FourCorners	DSW
WECC_NewMexico	DSW
WECC_Palo Verde	DSW

Step 6: Disaggregate regions back to areas and compile changeset to run in AURORA.

Draft Findings

Western Interconnection





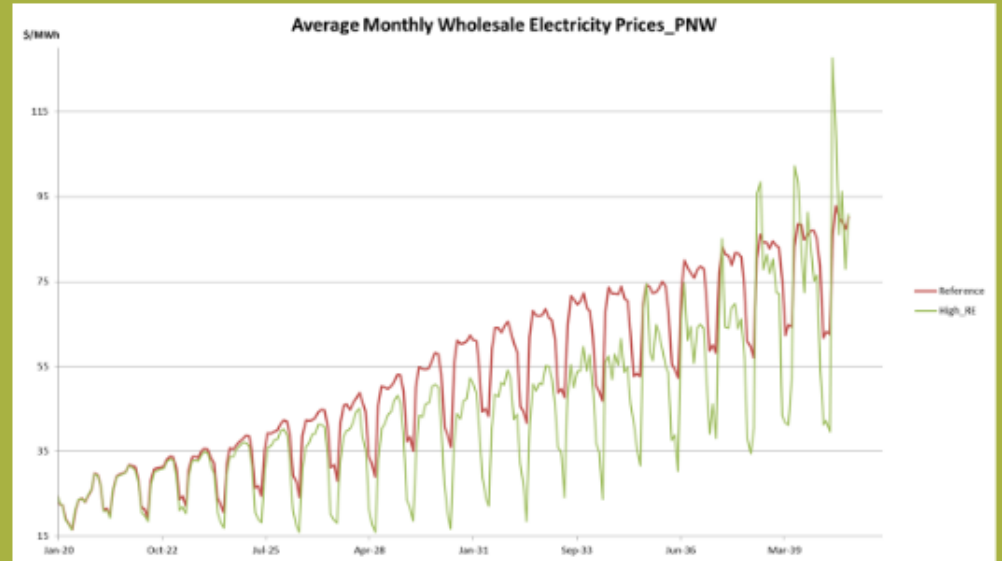
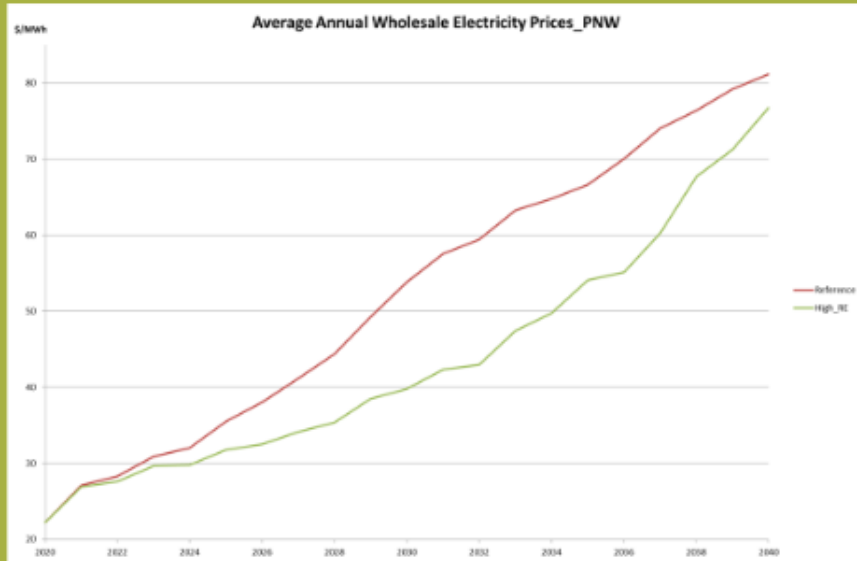
Draft Findings

- How do wholesale electricity prices respond?
- What is the resulting resource stack?
- How do resources operate?
- How are emissions affected?

Wholesale
Electricity
Prices

Resources
&
Operation

Emissions



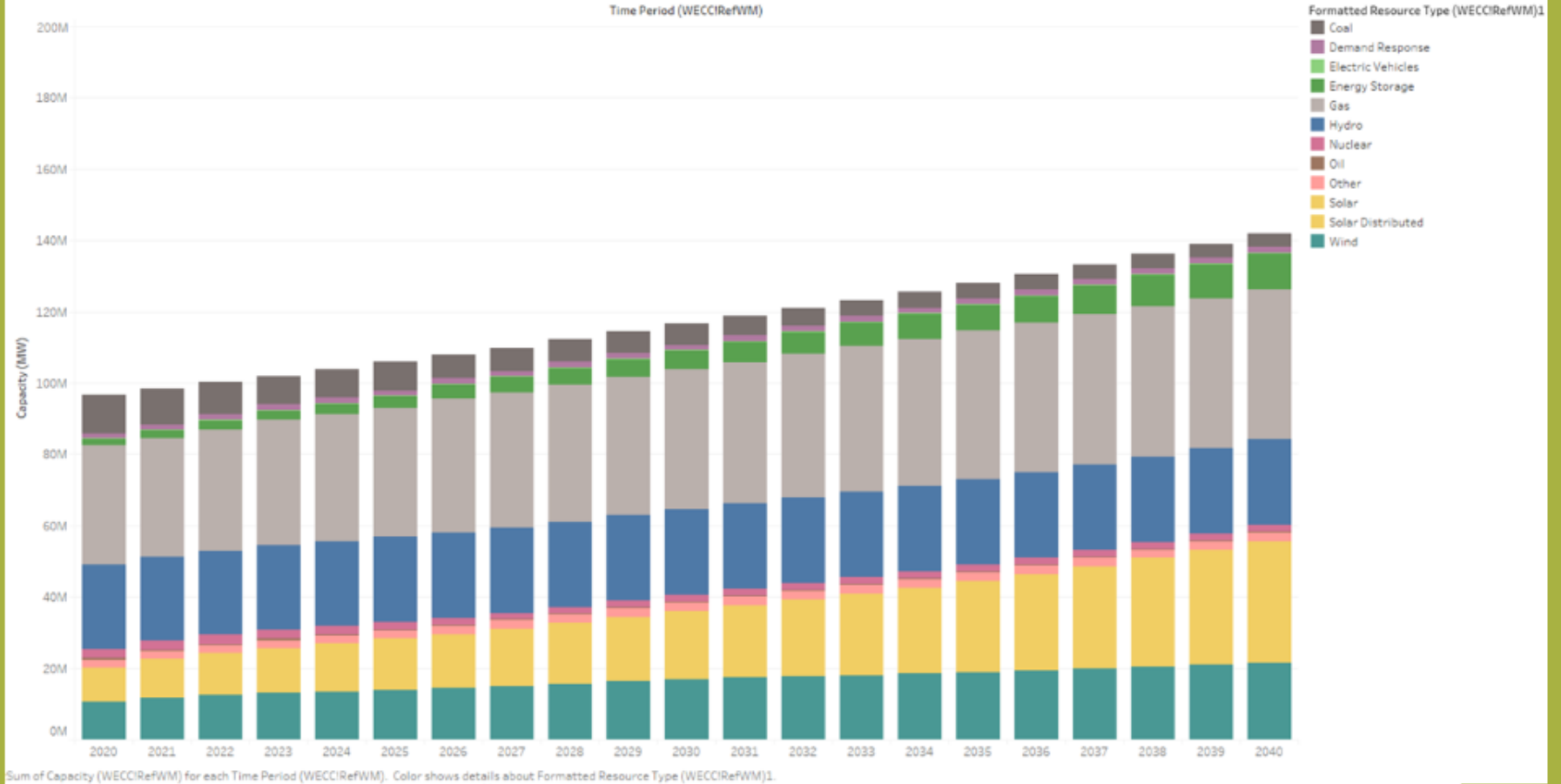
% Price Delta 2040

	1	2	3	4	5	6	7	8	9	10	11	12
1	-9%	-3%	-17%	-11%	6%	-18%	102%	26%	16%	21%	-9%	-3%
2	-4%	24%	-25%	4%	12%	-22%	96%	27%	14%	17%	-13%	-7%
3	6%	8%	-5%	10%	23%	-19%	97%	23%	14%	21%	-10%	-2%
4	2%	27%	-25%	0%	-7%	-18%	83%	22%	9%	5%	-16%	-4%
5	-1%	20%	7%	26%	30%	0%	93%	22%	13%	14%	-9%	-5%
6	4%	20%	0%	19%	24%	-2%	103%	25%	-1%	5%	2%	-3%
7	11%	26%	43%	11%	-32%	-35%	73%	32%	17%	21%	36%	13%
8	71%	29%	-21%	-91%	-101%	-90%	-19%	-7%	0%	90%	84%	89%
9	17%	-18%	-48%	-98%	-98%	-83%	-24%	-12%	-42%	3%	-55%	45%
10	-32%	-70%	-83%	-102%	-101%	-97%	-65%	-31%	-59%	-31%	-71%	8%
11	61%	-73%	-89%	-105%	-103%	-92%	60%	-22%	-77%	-50%	-81%	40%
12	-74%	-83%	-90%	-108%	-105%	-98%	-56%	-23%	-77%	-58%	-70%	-42%
13	-71%	-82%	-91%	-110%	-105%	-89%	-59%	-24%	-76%	-54%	-74%	-51%
14	69%	84%	-91%	-109%	-106%	-95%	-50%	3%	-71%	-62%	-79%	41%
15	-62%	-83%	-91%	-108%	-105%	-85%	-49%	8%	-62%	-66%	-75%	-42%
16	-29%	-66%	-87%	-106%	-103%	-83%	-23%	11%	-43%	-46%	5%	18%
17	4%	-23%	-90%	-103%	-101%	-86%	-33%	-3%	-30%	-15%	31%	19%
18	5%	32%	-65%	-100%	-101%	-81%	3%	6%	3%	62%	65%	20%
19	2%	38%	28%	7%	-2%	-14%	137%	65%	82%	80%	27%	17%
20	-7%	26%	63%	76%	97%	79%	213%	128%	109%	60%	20%	4%
21	-8%	9%	15%	27%	54%	50%	193%	70%	45%	47%	6%	0%
22	-13%	16%	22%	48%	54%	45%	149%	57%	24%	24%	-1%	4%
23	-13%	10%	-9%	-1%	4%	8%	110%	27%	21%	27%	1%	2%
24	-16%	12%	-13%	29%	4%	10%	99%	22%	5%	25%	3%	-1%

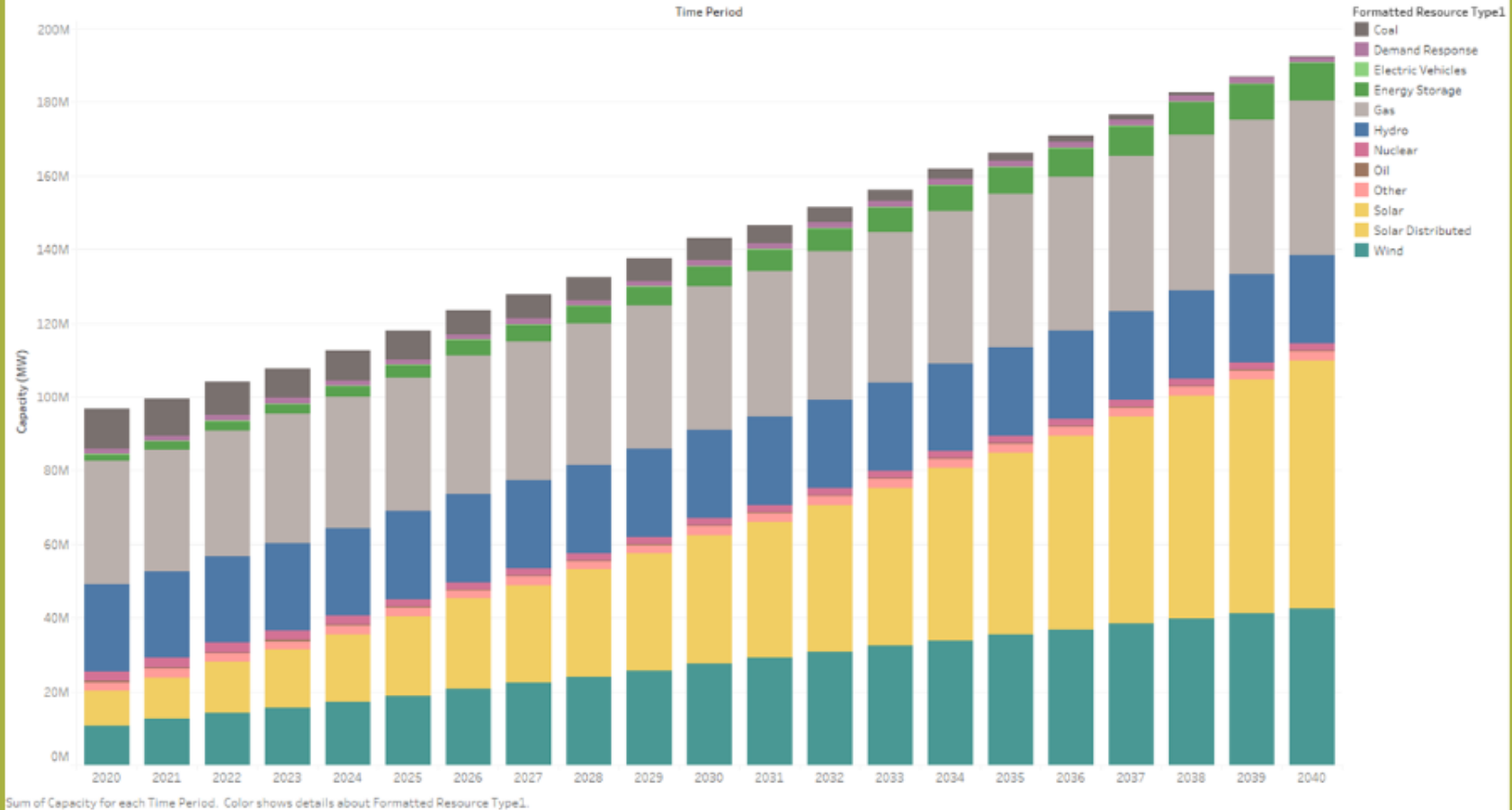
% Thermal Delta 2040

	1	2	3	4	5	6	7	8	9	10	11	12
1	-39%	-38%	-35%	-41%	-50%	-55%	-54%	-48%	-46%	-33%	-20%	-25%
2	-39%	-34%	-34%	-41%	-50%	-55%	-56%	-48%	-45%	-34%	-21%	-23%
3	-35%	-35%	-33%	-41%	-50%	-55%	-57%	-48%	-45%	-34%	-21%	-19%
4	-36%	-34%	-35%	-43%	-50%	-54%	-57%	-49%	-46%	-34%	-20%	-18%
5	-31%	-35%	-33%	-41%	-51%	-53%	-55%	-47%	-45%	-33%	-20%	-15%
6	-26%	-37%	-37%	-43%	-51%	-51%	-56%	-49%	-47%	-33%	-21%	-18%
7	-21%	-33%	-33%	-47%	-57%	-55%	-59%	-45%	-44%	-33%	-11%	-14%
8	-15%	-34%	-43%	-56%	-62%	-58%	-70%	-58%	-51%	-28%	-31%	-24%
9	-20%	-46%	-58%	-56%	-60%	-57%	-72%	-62%	-61%	-39%	-53%	-34%
10	-40%	-53%	-62%	-58%	-59%	-56%	-76%	-64%	-70%	-62%	-62%	-58%
11	-41%	-57%	-59%	-53%	-55%	-55%	-74%	-66%	-69%	-69%	-67%	-60%
12	-42%	-57%	-57%	-50%	-53%	-54%	-73%	-68%	-60%	-71%	-66%	-60%
13	-45%	-57%	-57%	-50%	-52%	-52%	-72%	-67%	-72%	-72%	-64%	-60%
14	-46%	-57%	-60%	-50%	-52%	-54%	-73%	-67%	-74%	-71%	-63%	-60%
15	-46%	-50%	-64%	-53%	-54%	-57%	-74%	-65%	-75%	-60%	-66%	-53%
16	-39%	-57%	-67%	-57%	-57%	-58%	-73%	-65%	-71%	-64%	-37%	-35%
17	-30%	-43%	-66%	-55%	-57%	-61%	-73%	-64%	-68%	-60%	-24%	-33%
18	-28%	-24%	-60%	-54%	-56%	-62%	-68%	-61%	-57%	-42%	-21%	-28%
19	-32%	-22%	-33%	-48%	-51%	-50%	-55%	-50%	-37%	-29%	-21%	-30%
20	-31%	-22%	-20%	-40%	-43%	-50%	-41%	-35%	-30%	-28%	-22%	-27%
21	-33%	-28%	-31%	-42%	-45%	-48%	-36%	-37%	-38%	-33%	-21%	-27%
22	-33%	-28%	-33%	-43%	-46%	-51%	-38%	-43%	-42%	-35%	-19%	-27%
23	-33%	-32%	-37%	-44%	-50%	-54%	-47%	-47%	-46%	-35%	-18%	-27%
24	-36%	-33%	-33%	-40%	-50%	-54%	-54%	-50%	-44%	-33%	-16%	-26%

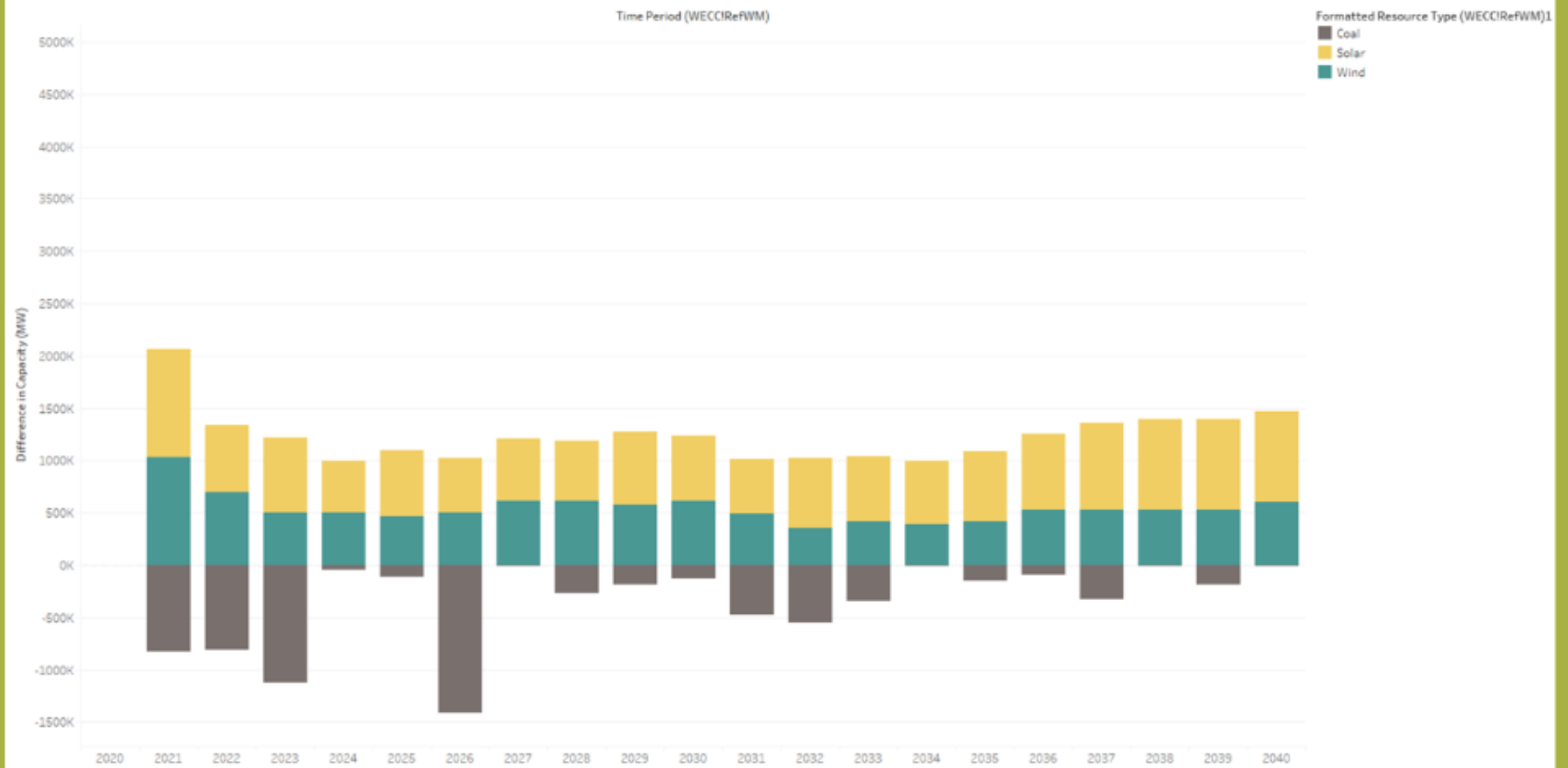
WECC Nameplate Capacity (MW)_Reference



WECC Nameplate Capacity (MW)_HighRE



WECC Capacity Additions (MW)_Reference



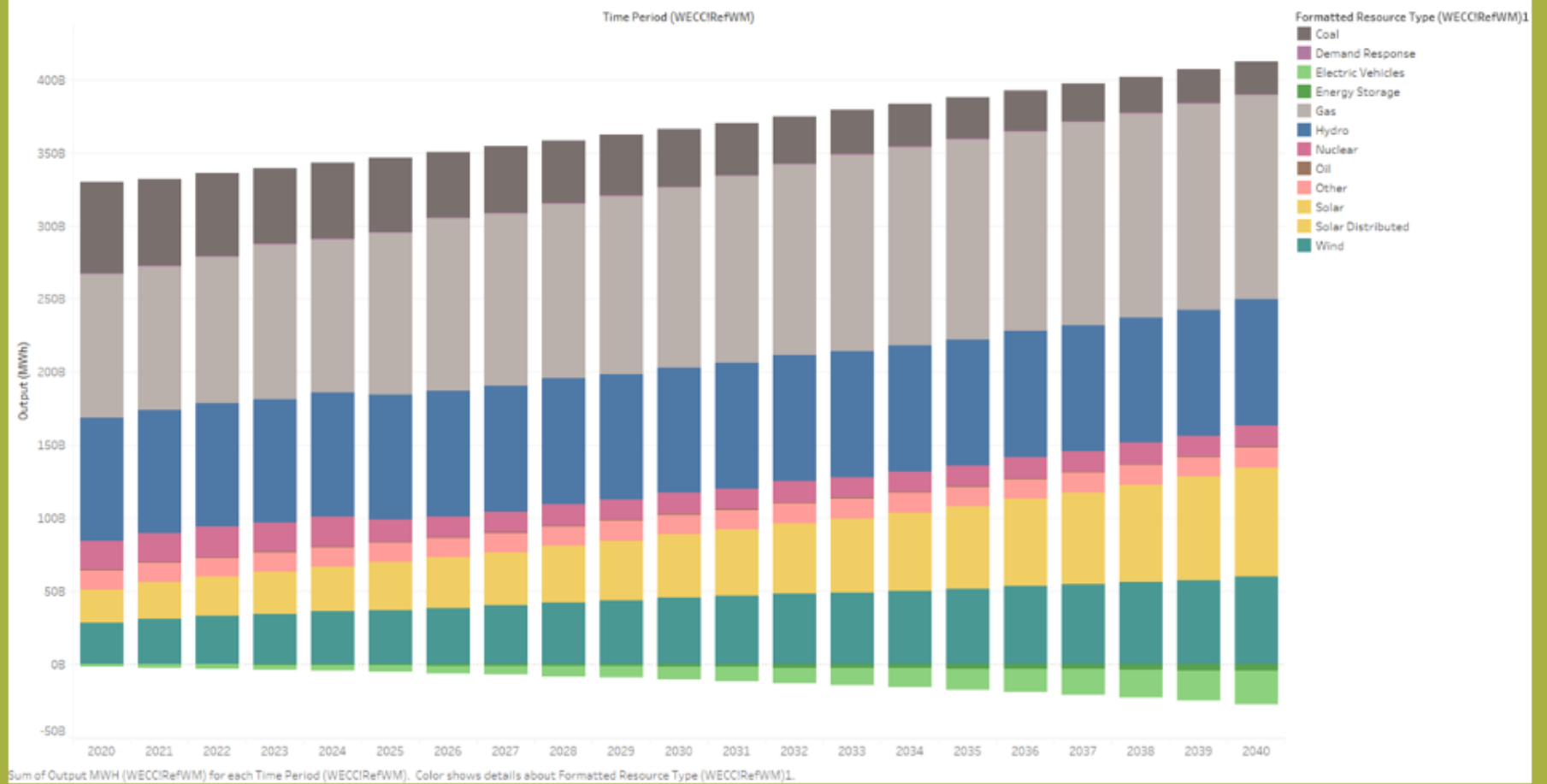
Difference in Capacity (WECCIRFWM) for each Time Period (WECCIRFWM). Color shows details about Formatted Resource Type (WECCIRFWM)1. The view is filtered on Formatted Resource Type (WECCIRFWM)1, which keeps Coal, Solar and Wind.

WECC Capacity Additions (MW)_HighRE

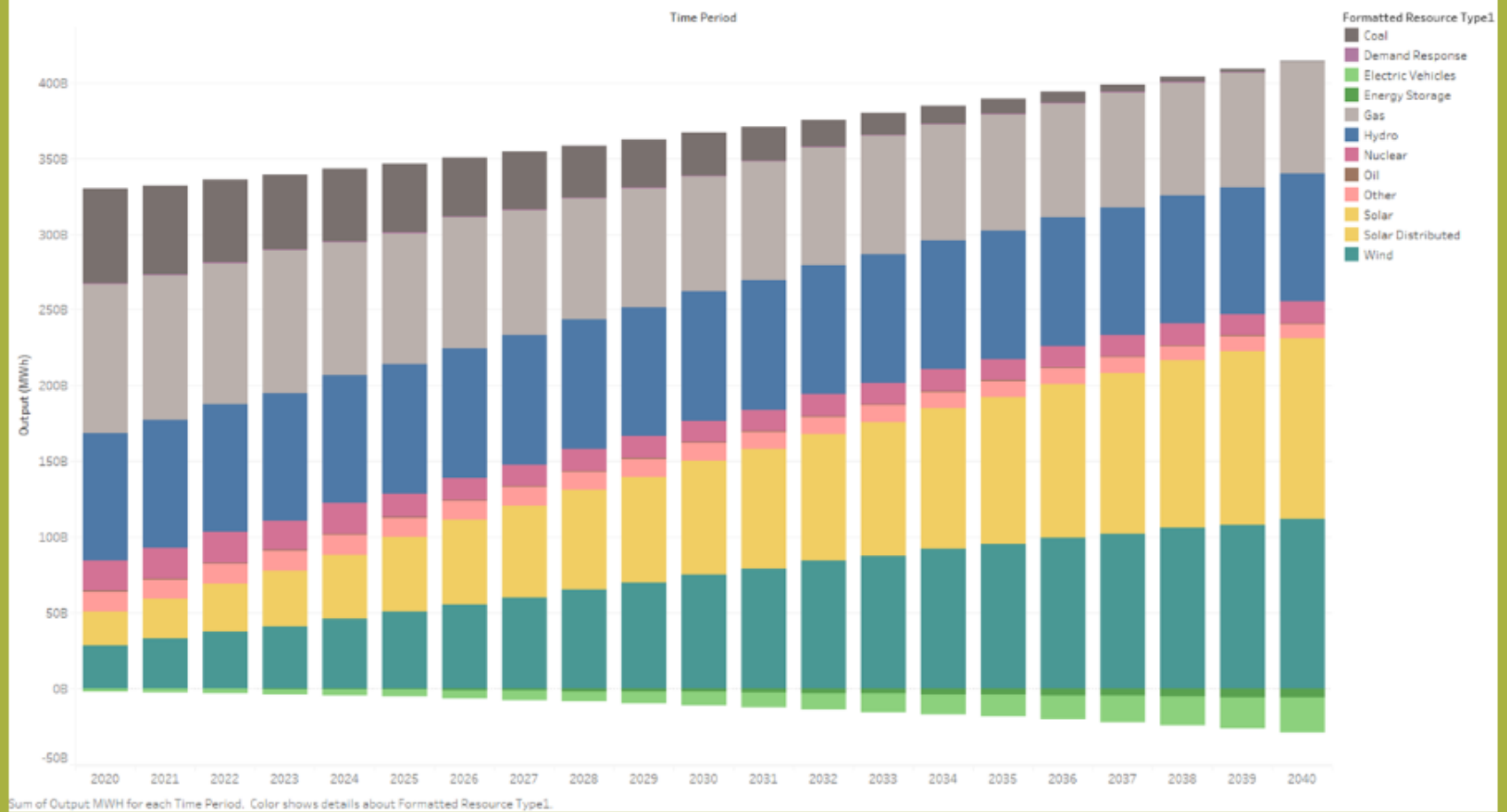


Difference in Capacity for each Time Period. Color shows details about Formatted Resource Type1. The view is filtered on Formatted Resource Type1, which keeps Coal, Solar and Wind.

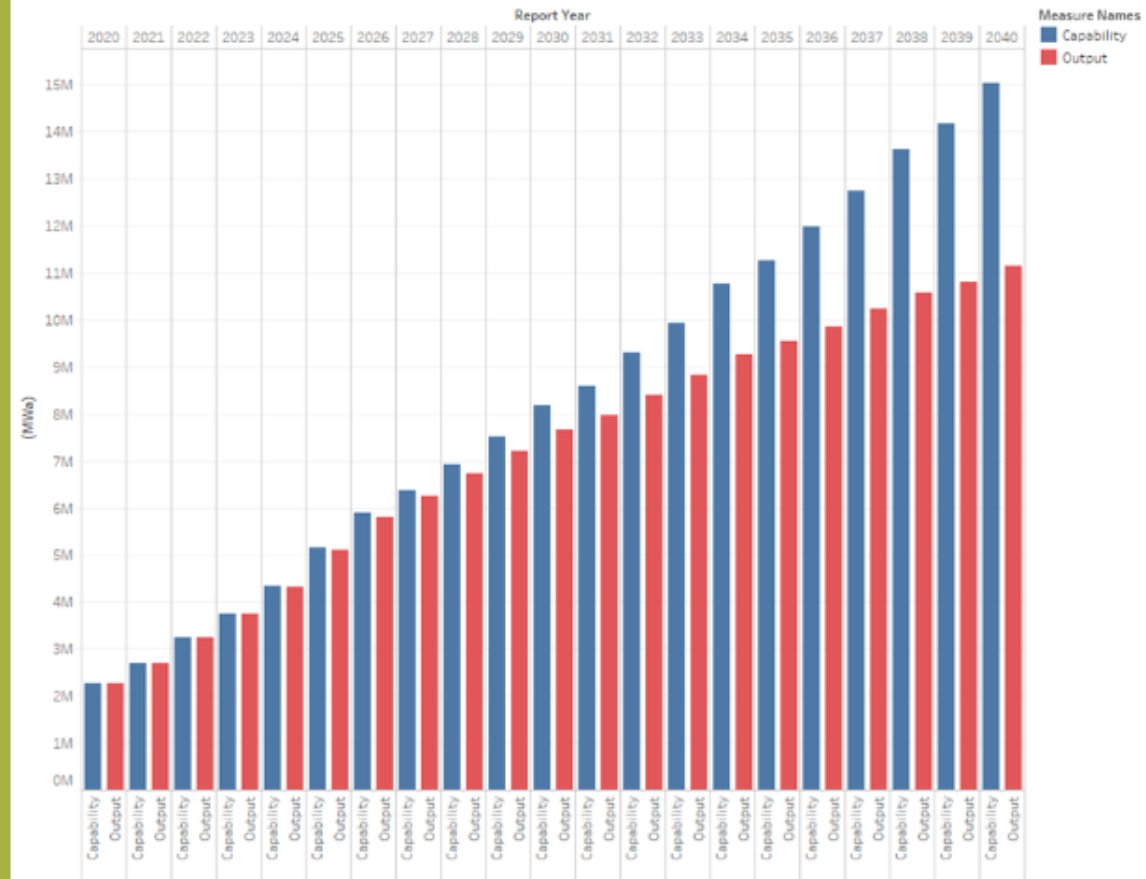
WECC Total Generation (MWh)_Reference



WECC Total Generation (MWh)_High RE

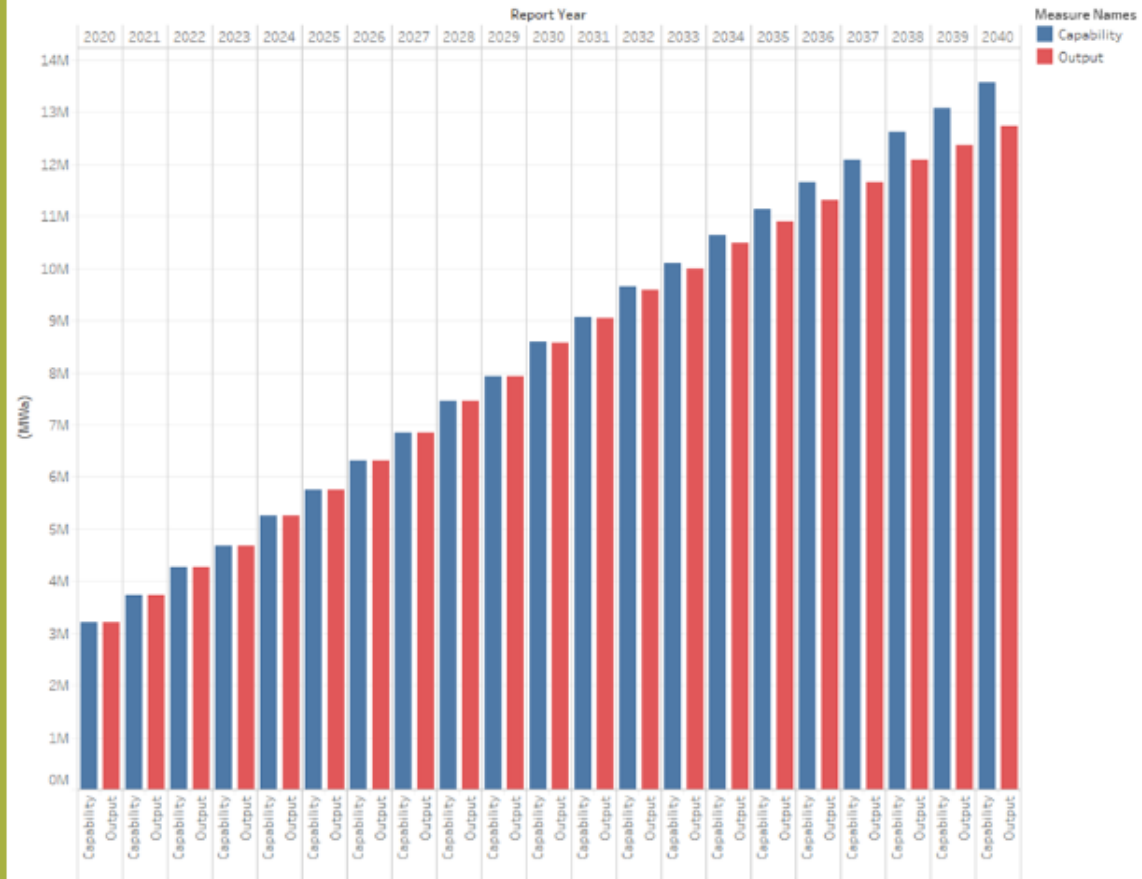


WECC Solar Curtailment (MWa)_HighRE



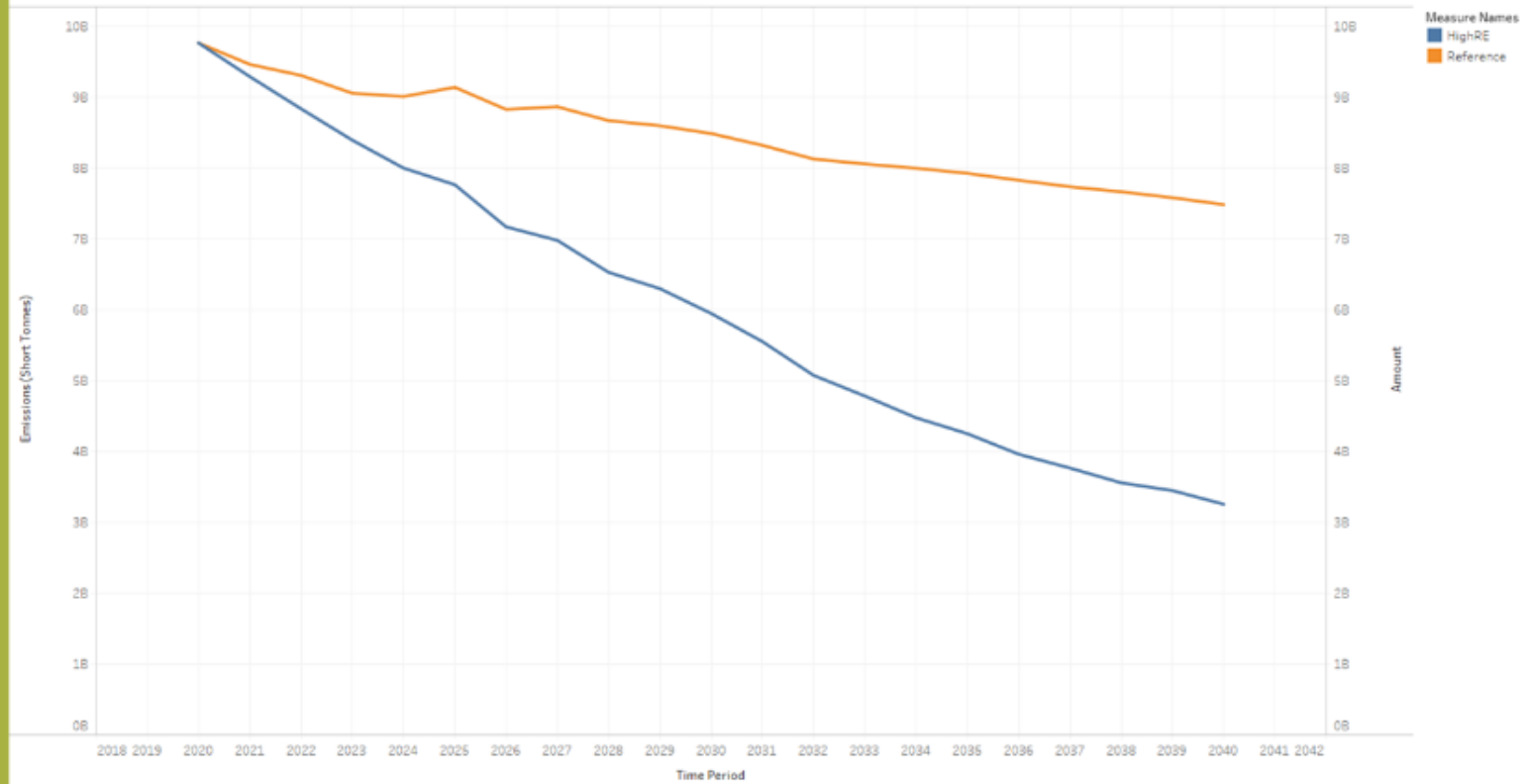
Capability and Output for each Report Year. Color shows details about Capability and Output. The data is filtered on Formatted Resource TypeL, which keeps Solar.

WECC Wind Curtailment (MWa)_HighRE



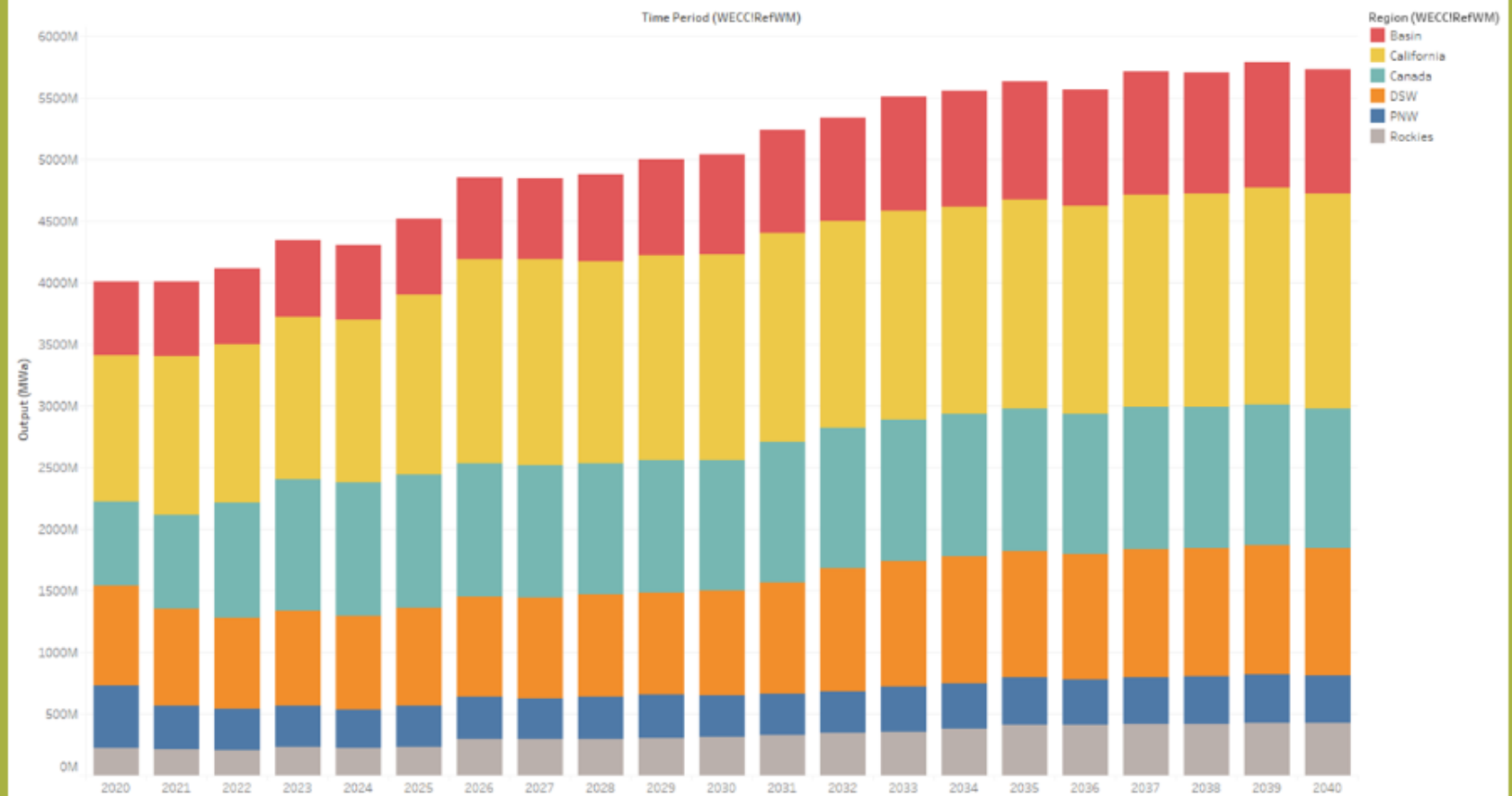
Capacity and Output for each Report Year. Color shows details about Capacity and Output. The data is filtered on Resource Type, which keeps Wind.

WECC CO2 Emissions Delta (Short Tonnes)



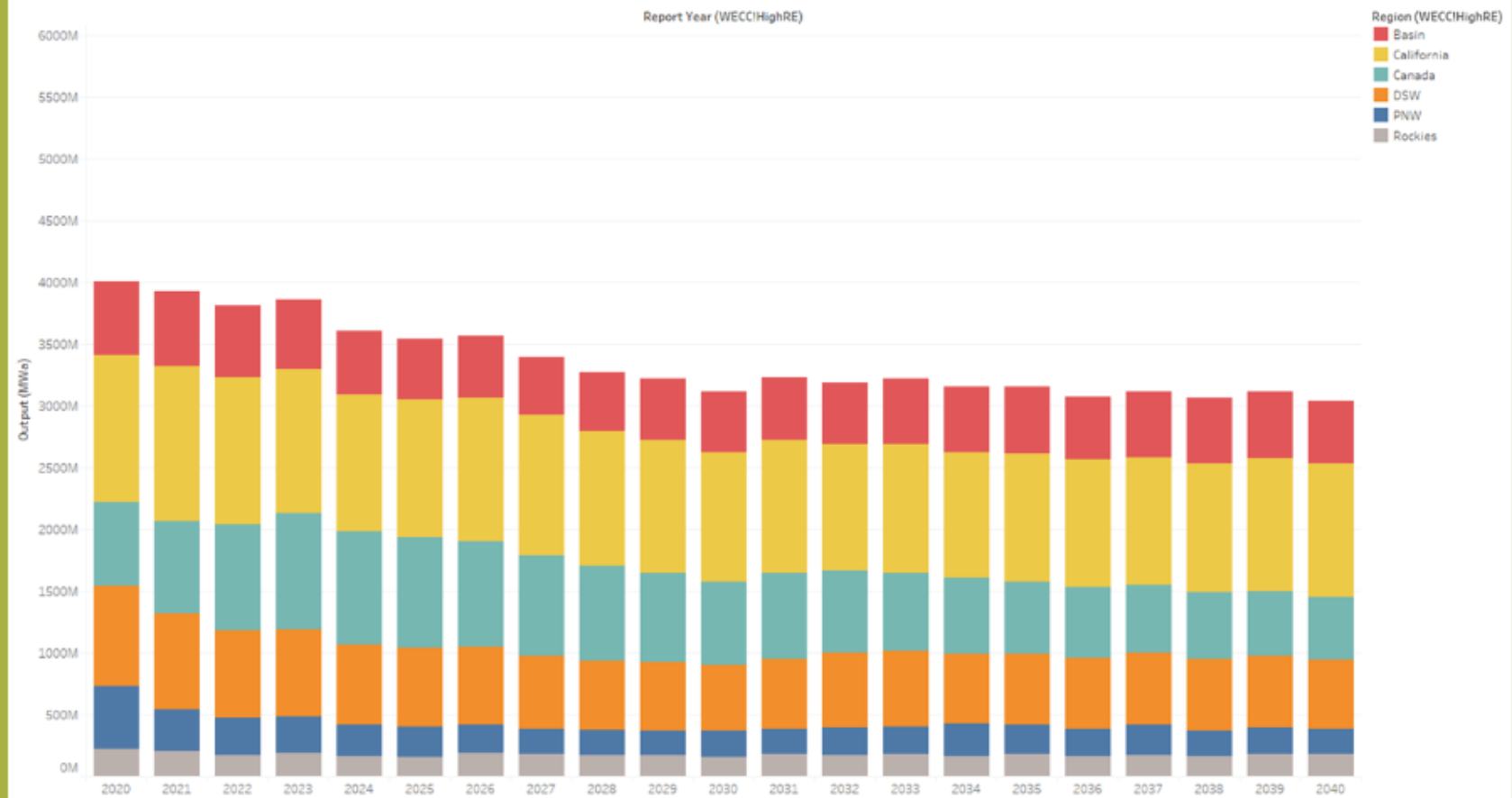
The trends of Reference and HighRE for Time Period. Color shows details about Reference and HighRE. The data is filtered on Type1 and Type (Emissions|Ref)1. The Type1 filter keeps CO2. The Type (Emissions|Ref)1 filter keeps CO2.

Regional Gas Output (MWa)_Reference



Sum of Output (WECCIReFWM) for each Time Period (WECCIReFWM). Color shows details about Region (WECCIReFWM). The data is filtered on Formatted Resource Type (WECCIReFWM), which keeps Gas.

Regional Gas Output (MWa)_HighRE



Sum of Output (WECC|HighRE) for each Report Year (WECC|HighRE). Color shows details about Region (WECC|HighRE). The data is filtered on Formatted Resource Type (WECC|HighRE), which keeps Gas.



WECC-Wide High Renewable Buildout

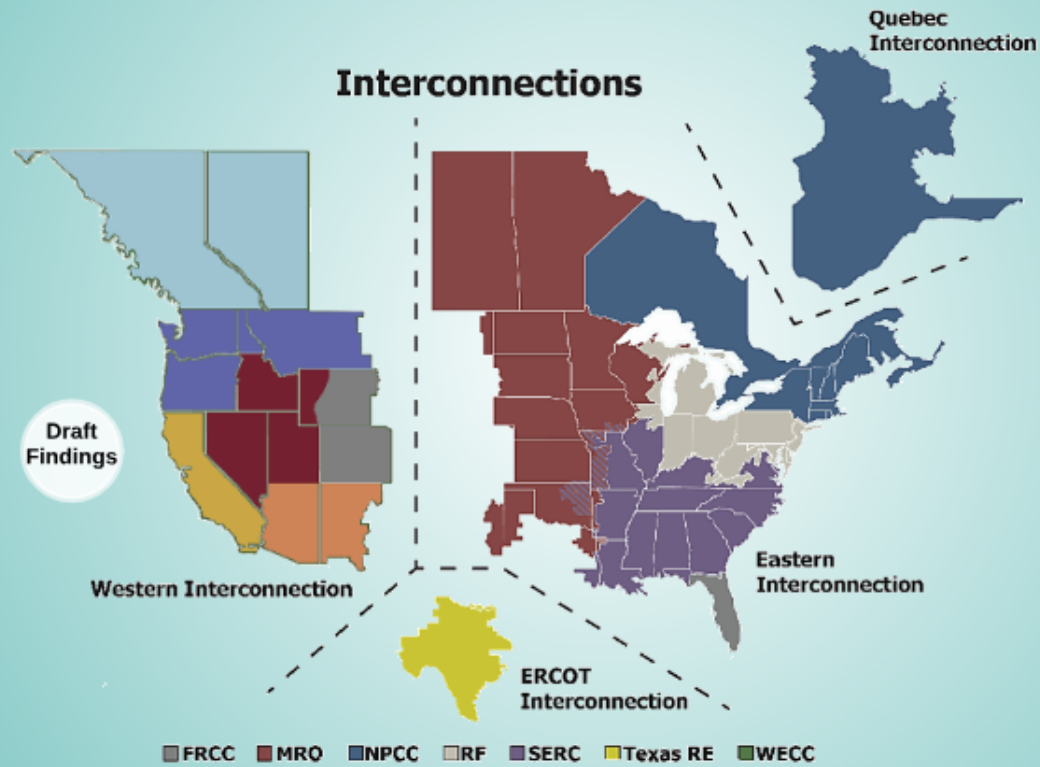


Image: NERC