# Oregon Clean Energy Pathways Final Report

June 15, 2021

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# Contents

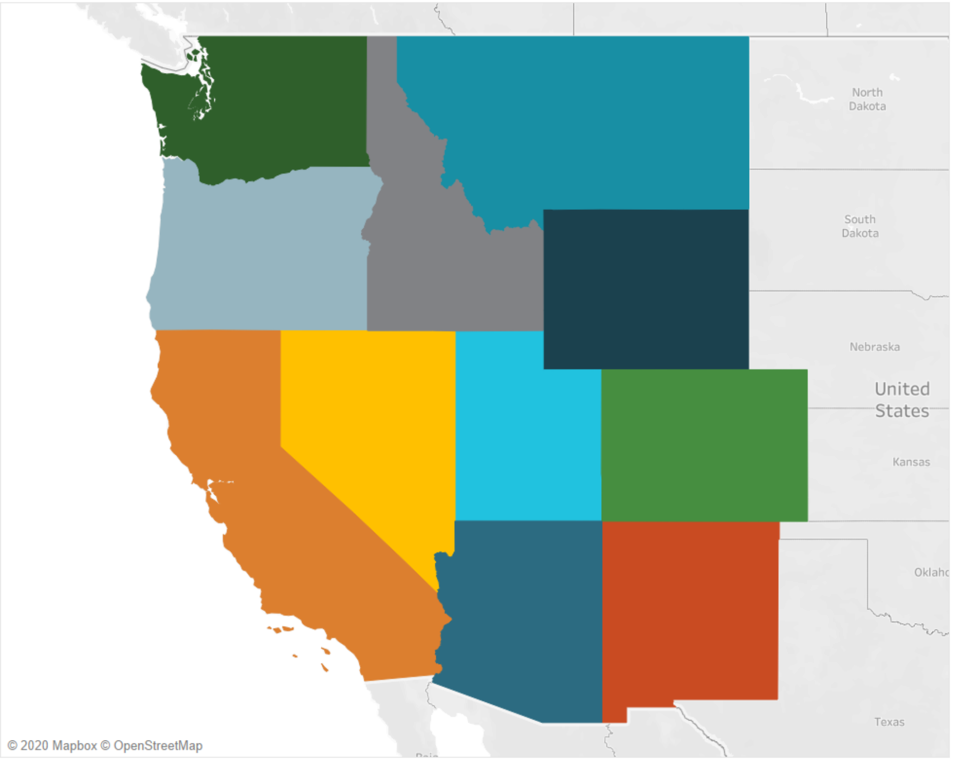
# Goals of the Project

- Examine technical and economic implications of accelerating decarbonization in Oregon
  - Results intended to inform policymaking in Oregon

- *What if Oregon had an economy-wide, net-zero emissions target?*
- *What if Oregon were restricted from building new gas plants?*
- *What if Oregon had to meet its emissions and clean electricity targets with only in-state resources?*
- *What if Oregon moved more slowly on transitioning energy-consuming technologies to clean alternatives through electrification?*

# Study Evaluates Clean Energy Pathways for Oregon

Wholistic approach, integrated across geographies and economic sectors




- **Explores** pathways to achieve Oregon's electricity and emissions targets by considering the transition needed in all sectors of the economy
- **Modeling determines optimal investment** in resources, constrained by scenario definitions, investigating different potential state objectives or uncertainties
- **Decarbonizing the energy supply**—electricity, pipeline gas, liquid fuels
- **Conservative** assumptions about existing technologies and cost projections from public sources
- Models integrate electricity and fuels systems that extend beyond Oregon's borders to **capture regional opportunities and challenges**
  - Other states' actions will impact the availability and cost of solutions Oregon has to transition to clean energy



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# Review of Modeling Approach

# High Level Description of Modeling Approach

- Model calculates the energy needed to power the Oregon economy, and the least-cost way to provide that energy under clean electricity and emissions goals

**Model of Oregon's economy**

Residential
Commercial
Industrial
Transportation

**1: Model calculates energy needs**

**Oregon's energy needs**

Electricity
Liquid Fuels
Gaseous Fuels

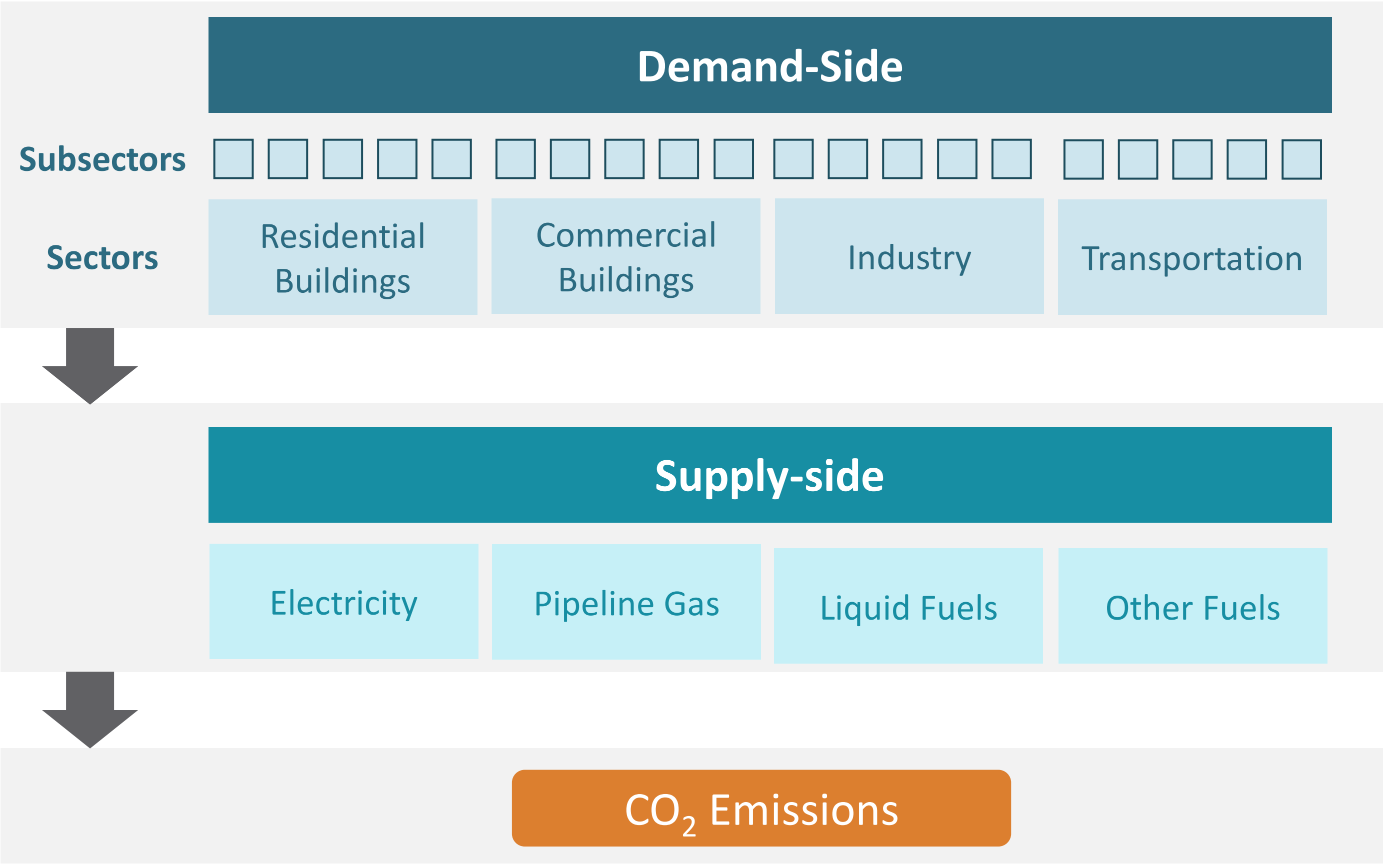
**2: Model calculates energy supply**

Constrained by clean energy goals

**Supply energy reliably at least cost**

Generation
Transmission
Storage
Fuel supply
Carbon

# Analysis Covers Oregon's Entire Energy System




- **EnergyPATHWAYS** model used to develop demand-side cases
- Applied electrification and energy efficiency levers
- Strategies vary by sub-sector (residential space heating to heavy duty trucks)

- **Regional Investment and Operations (RIO)** model identifies cost-optimal energy supply
- Net-zero electricity systems
- Novel technology deployment (biofuels; hydrogen production; geologic sequestration)



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# Demand-Side Modeling

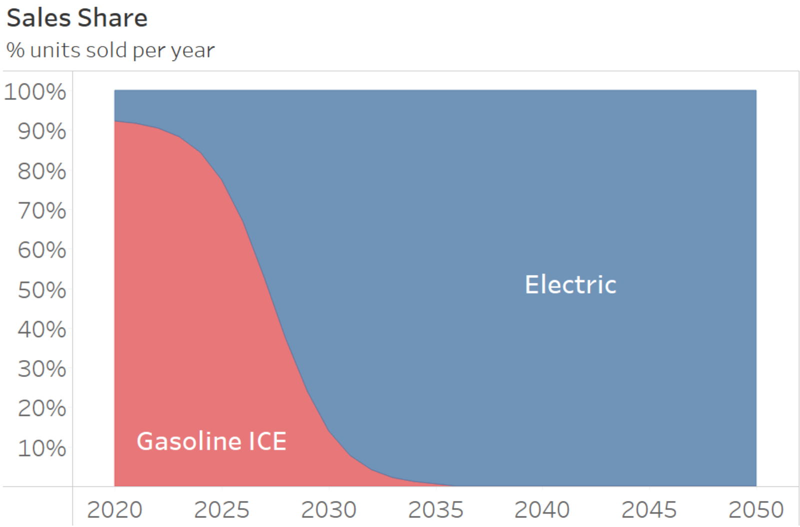
- Scenario-based, bottom-up energy model (not optimization-based)
- Characterizes rollover of stock over time
- Simulates the change in total energy demand and load shape for every end use

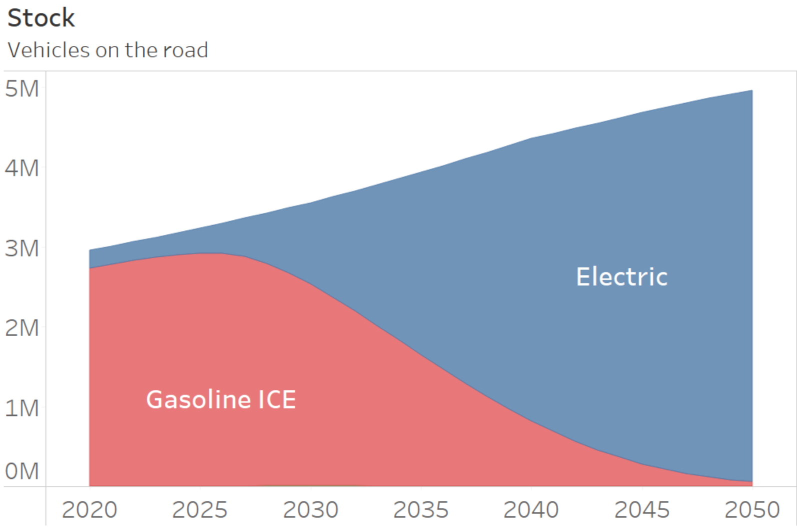
***Illustration of model inputs and outputs for light-duty vehicles***

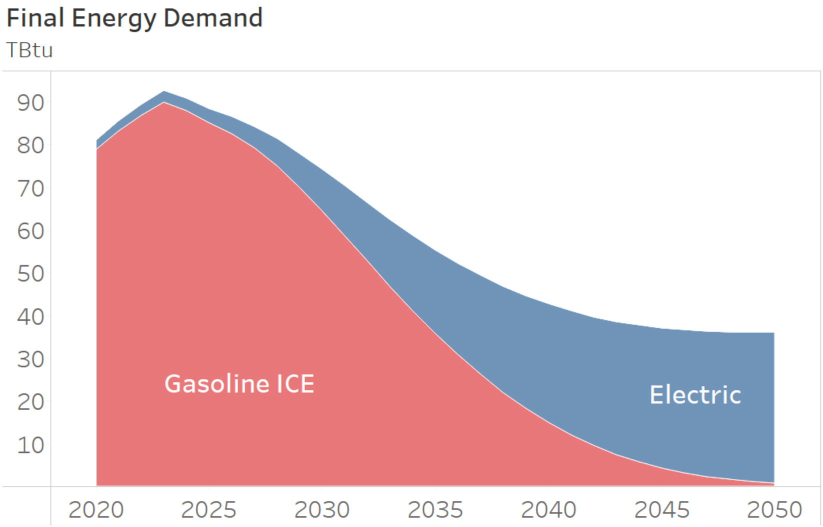
**Input: Consumer Adoption**
EV sales are 100% of consumer adoption by 2035 and thereafter

**Output: Vehicle Stock**
Stocks turn-over as vehicles age and retire

**Output: Energy Demand**
EV drive-train efficiency results in a drop in final-energy demand



# End-Use Sectors Modeled

- Approximately 70 demand sub-sectors represented
- The major energy consuming sub-sectors are listed below:

**Key energy-consuming subsectors.**

**Residential Sector**
- Air-conditioning
- Space heating
- Water heating
- Lighting
- Cooking
- Dishwashing
- Freezing
- Refrigeration
- Clothes washing
- Clothes drying

**Commercial Sector**
- Air-conditioning
- Space heating
- Water heating
- Ventilation
- Lighting
- Cooking
- Refrigeration

**Industrial Sector**
- Boilers
- Process heat
- Space heating
- Curing
- Drying
- Machine drives
- Additional subsectors (e.g., machinery, cement)

**Transportation Sector**
- Light-duty autos
- Light-duty trucks
- Medium-duty vehicles
- Heavy-duty vehicles
- Transit buses
- Aviation
- Marine vessels

Source: CETI, NWDDP, 2019

# Supply Side Modeling

Optimized investments in energy infrastructure

## Example: Electricity

Electricity includes all economic sectors ➡ Model optimizes investments to meet demand, reliability, and emission targets

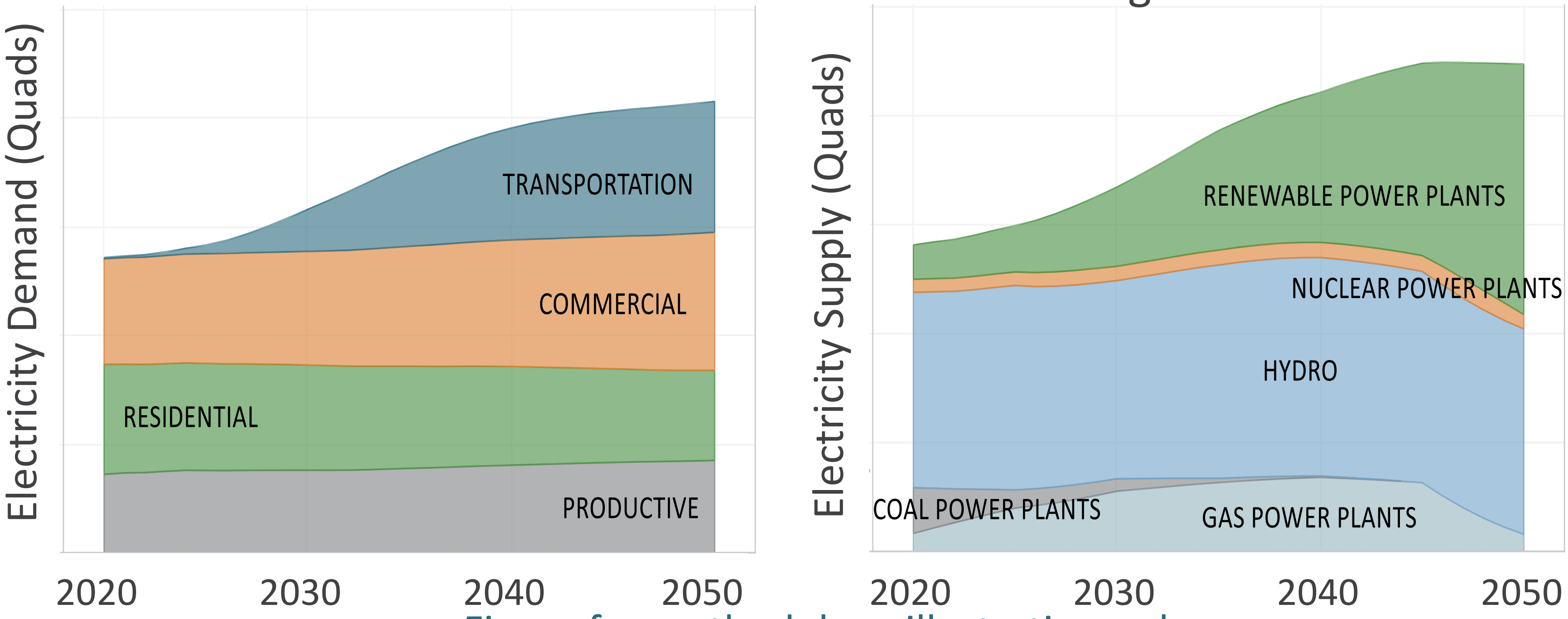



Figure for methodology illustration only

- **Reliability**: Model requires supply is met during rare, severe weather events, while maintaining reserve margin
- Fuel and electricity supply are optimized together
- Model uses best available public data



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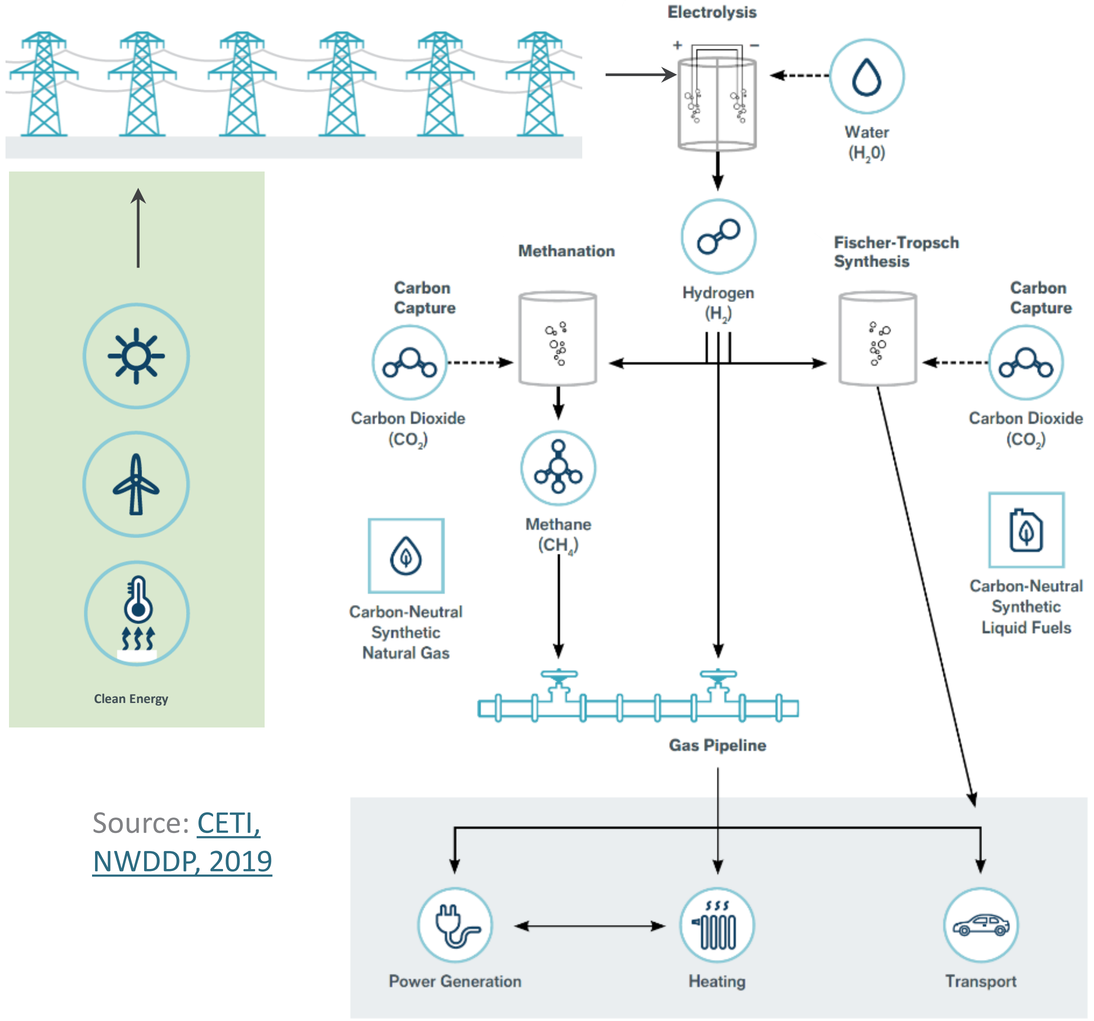
# Integrated Supply Side: Electricity and Fuels

- Conventional means of "balancing" may not be the most economic or meet clean energy goals
- New opportunities: Storage and flexible loads
- Fuels are another form of energy storage
- Large flexible loads from producing decarbonized fuels:
  - Electrolysis, synthetic fuels production




Source: CETI, NWDDP, 2019



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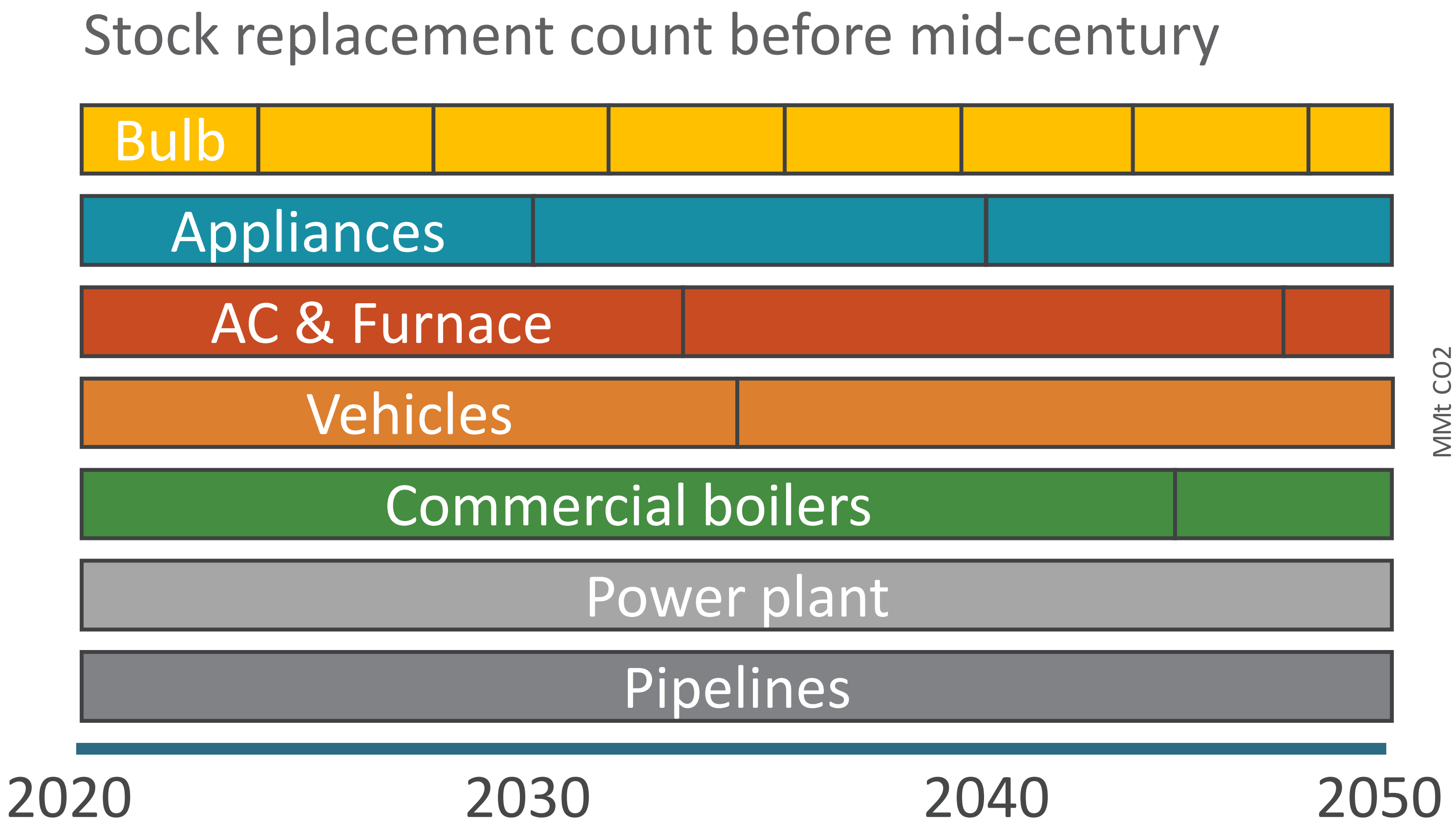
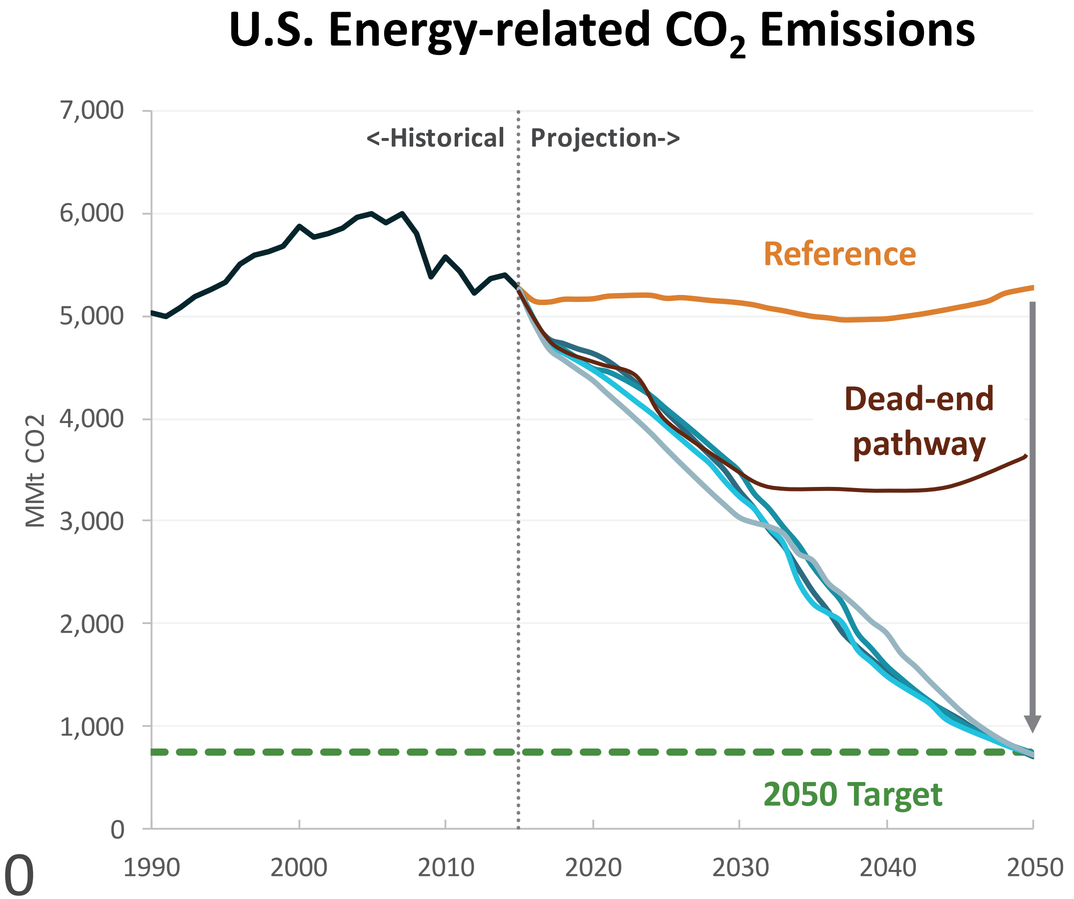
# Near-Term Focus on Long-Lived Assets

Long-lived infrastructure should be an early focus to avoid carbon lock-in or stranded assets

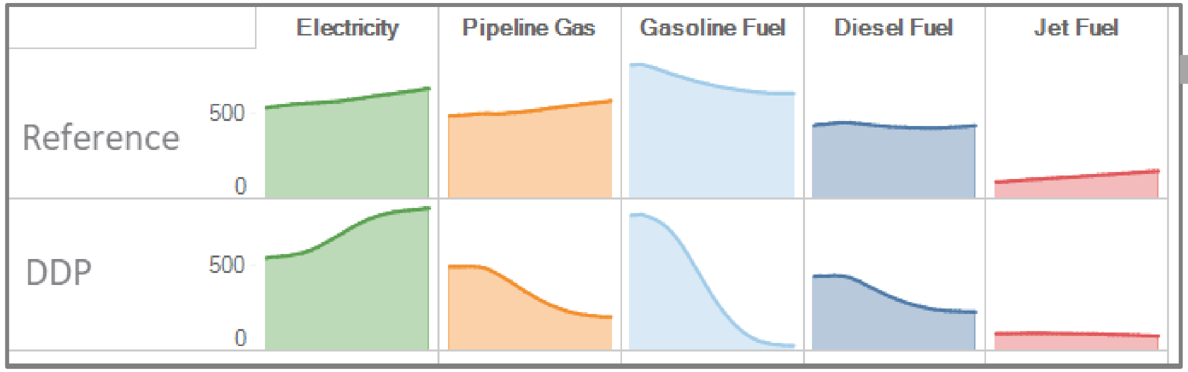


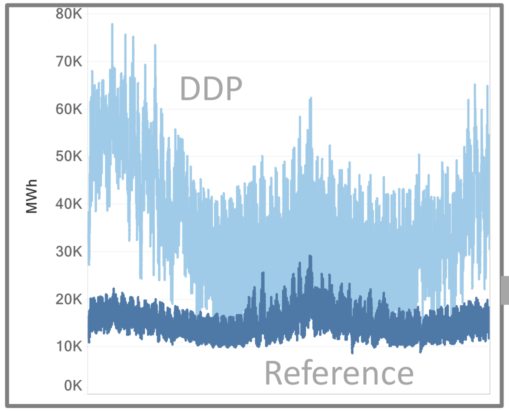
# Demand- and Supply-Side Modeling Framework

## EnergyPATHWAYS (EP)

### Annual End-Use Energy Demand




### Hourly Load Shape




## Regional Investment and Operations (RIO)

### Inputs

- End-use energy demand
- System emissions constraints
- RPS or CES constraints
- Technology and fuel cost projections
- New resource constraints
- Biomass and $CO_2$ Sequestration costs
- Hourly load shape

### Outputs

**Electricity sector**
- Wind/solar build
- Energy storage capacity/duration
- Capacity for reliability
- Curtailment
- Hourly operations

Hydrogen production

Synthetic electric fuel production (H2/SNG)

Biomass allocation

$CO_2$ sequestration



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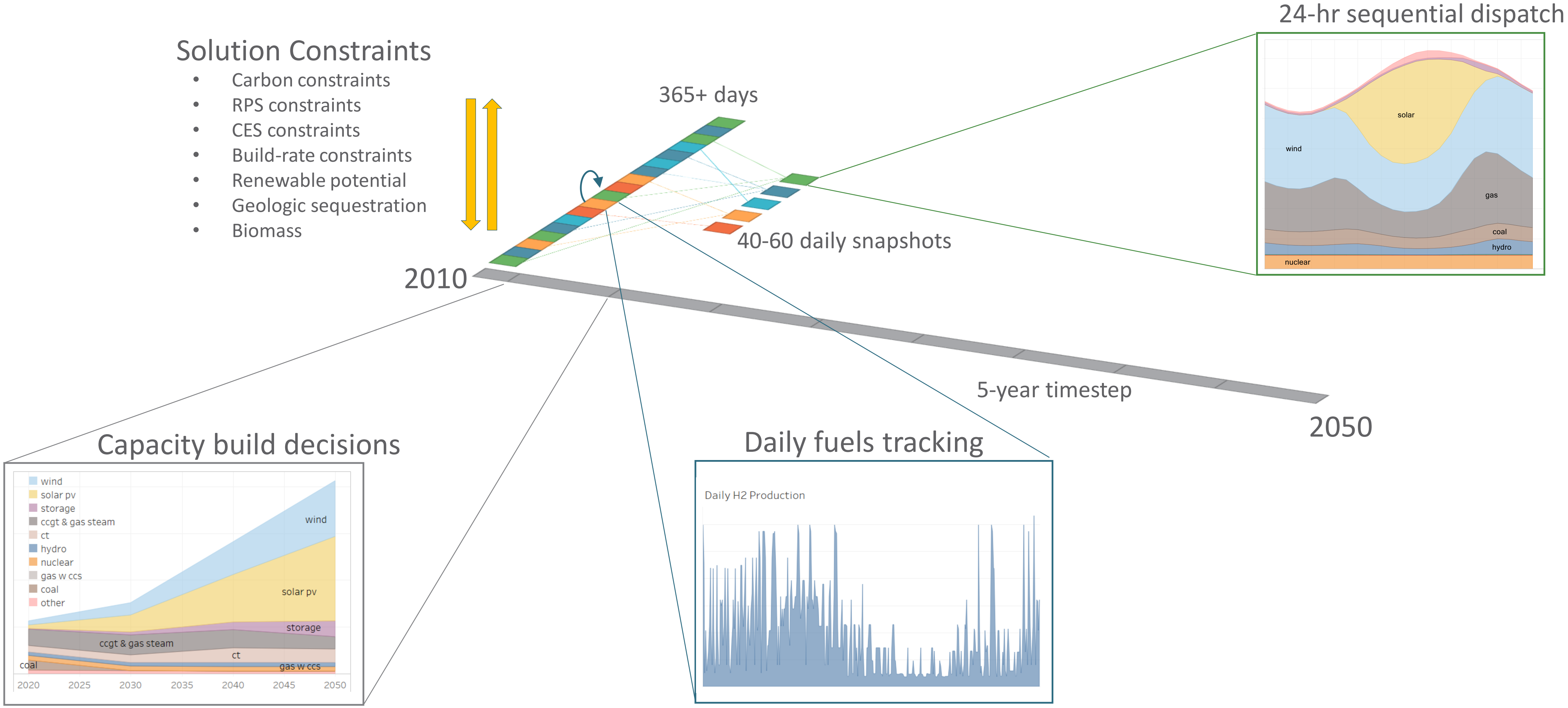
# RIO Optimizes across Time-Scales

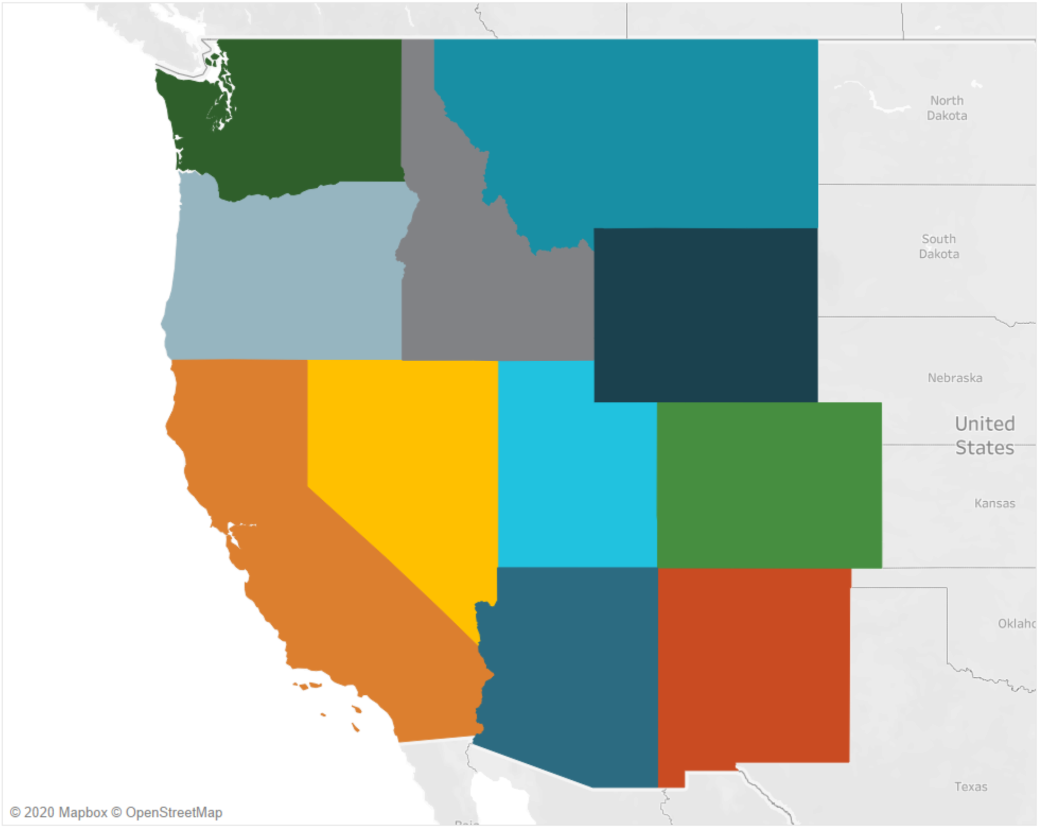
## Solution Constraints

- Carbon constraints
- RPS constraints
- CES constraints
- Build-rate constraints
- Renewable potential
- Geologic sequestration
- Biomass



# RIO Optimizes across Geographic Constraints

- Transmission constraints and potential between states
  - Model can optimally expand interties and fuels delivery infrastructure
- Loads, resources, and new resource potentials by state
  - Captures unique geographic advantages and local conditions by state
- Oregon is integrated into the West-wide/US-wide transmission network of electricity and fuels, and decarbonization solutions depend on this integration
  - Opportunity for coordination across states





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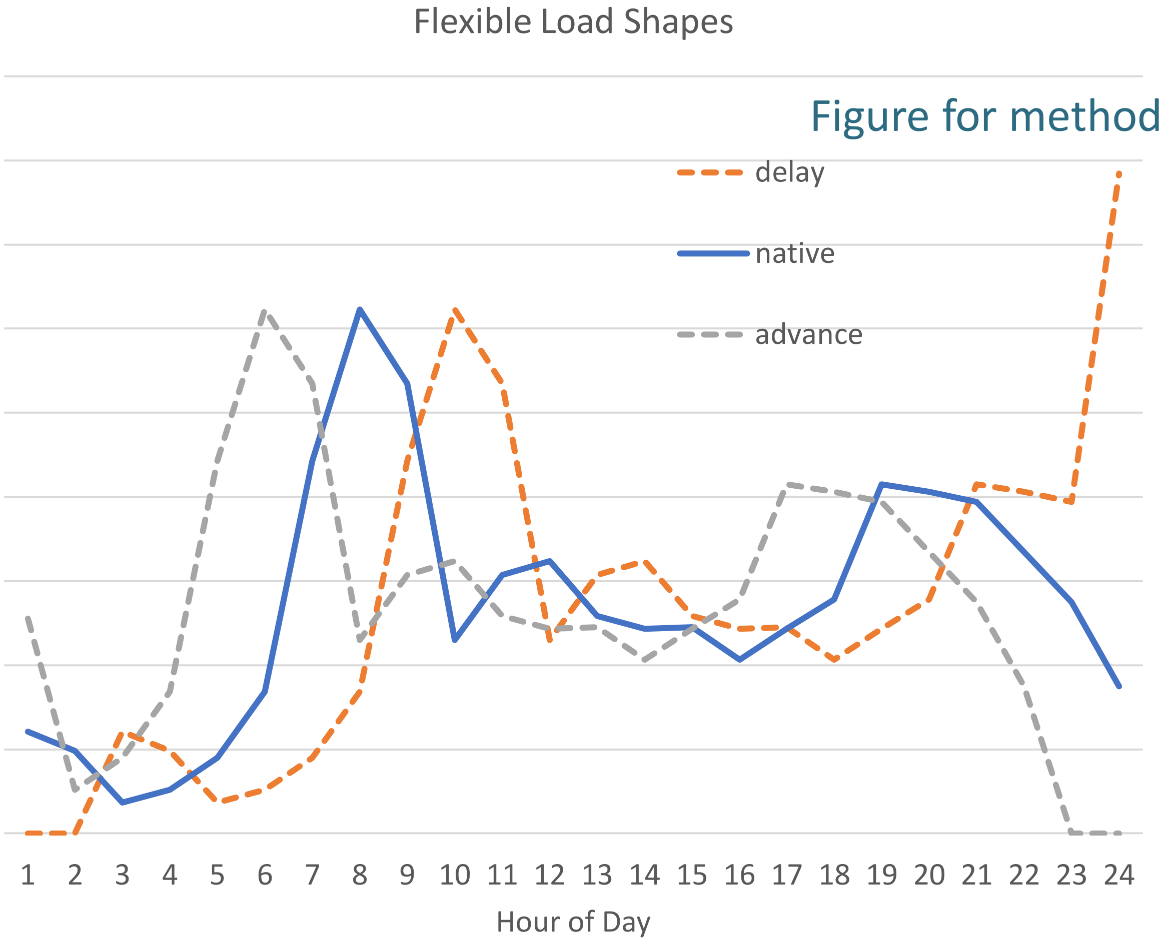
# Flexible Load Operations

## Cumulative energy constraints

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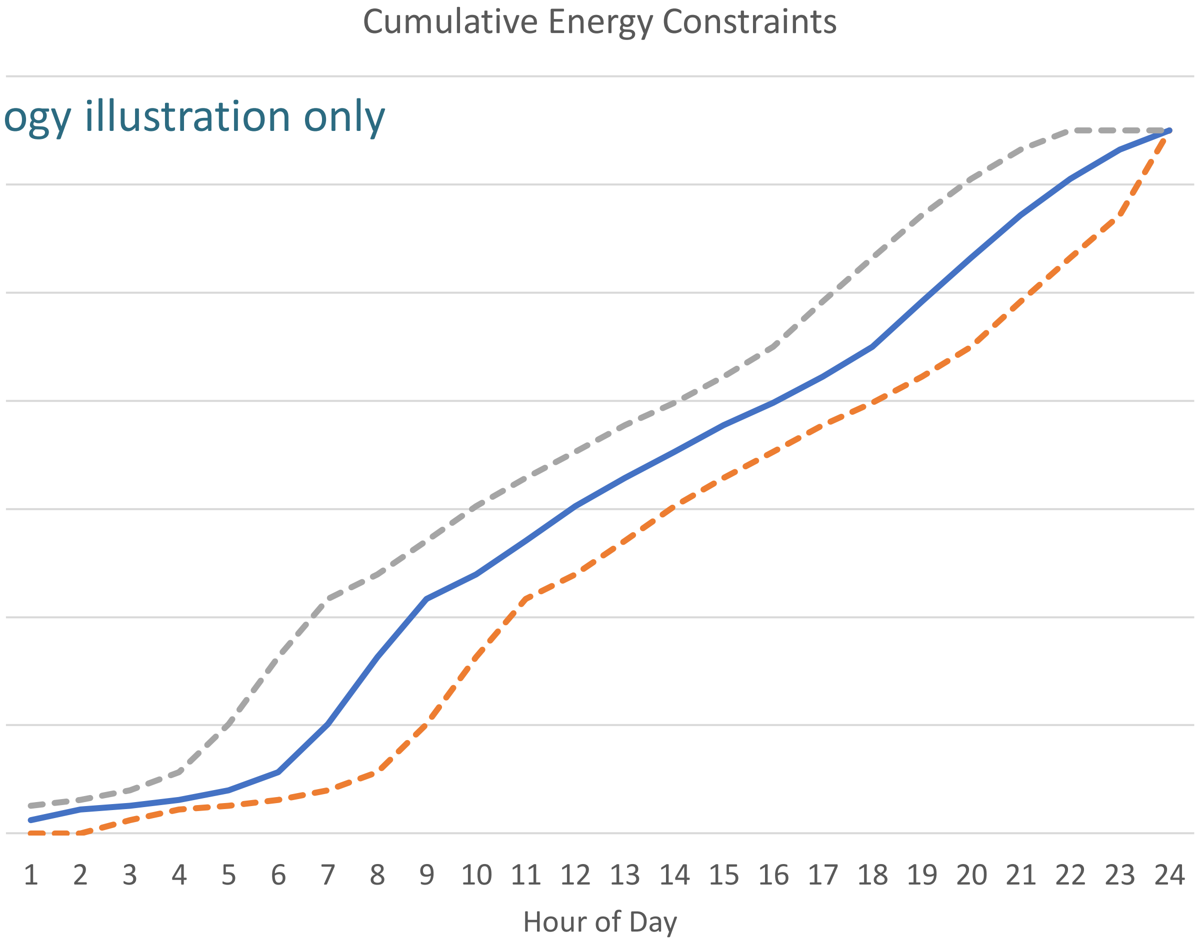
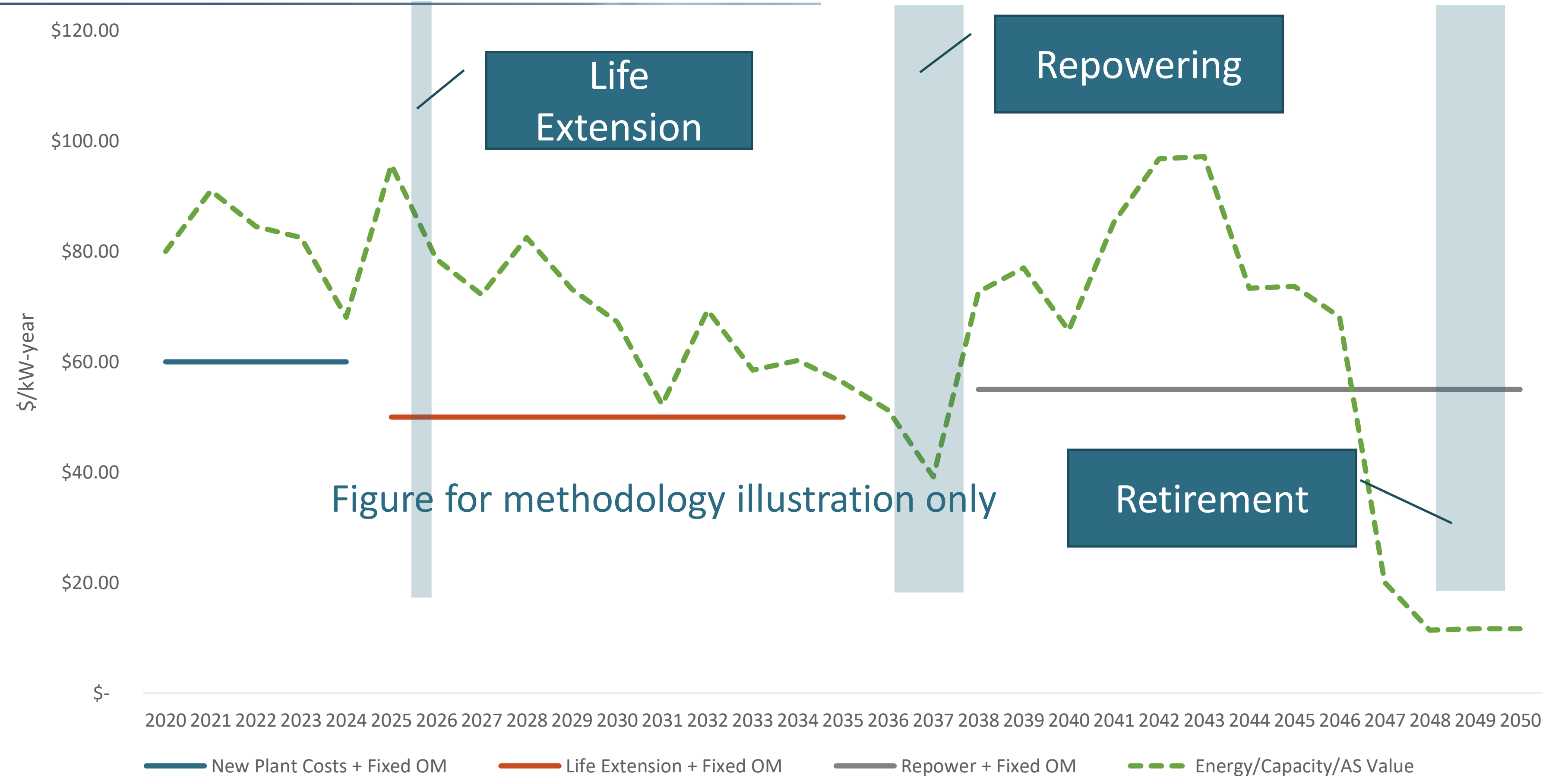


# Economic Generator Lifecycles

RIO optimizes plant investment decisions including life extensions, repowering, and retirements based on system value and ongoing costs



# Electricity and Fuels Sector Integration

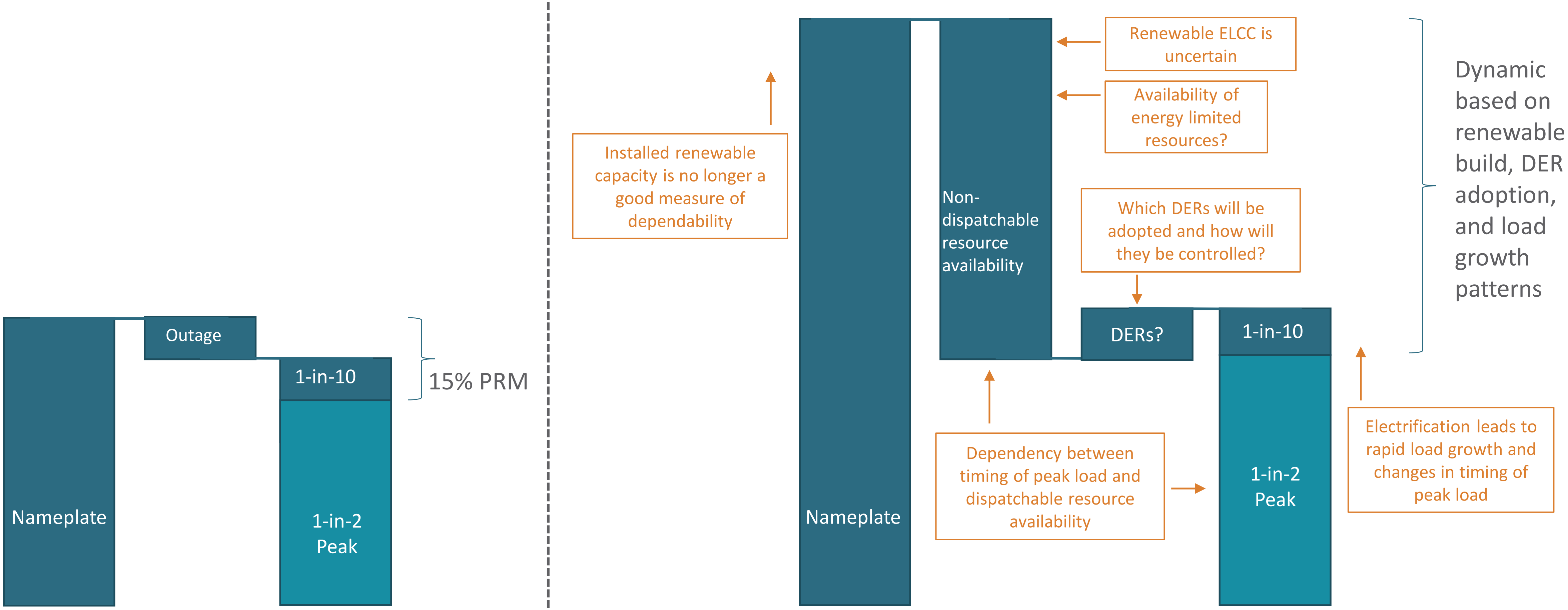
- Traditional capacity expansion approaches have narrowly defined the problem in terms of the electric sector
- Decarbonization and pushes towards 100% renewables have revealed the inadequacy of that approach as both will require sectoral integration
- A key opportunity for sectoral integration is in the fuel-supply sector, as it may be counted on to provide low-carbon fuels for thermal generation/primary end uses and provide electricity balancing services to the grid
- Endogenizing decisions in both allows us to explore opportunities for sectoral integration that have escaped other modeling frameworks

# Hourly Reserve Margin Constraints by Zone

## Assessing Reliability Becomes Challenging in Low-Carbon Electricity Systems

### Traditional Reserve Margin

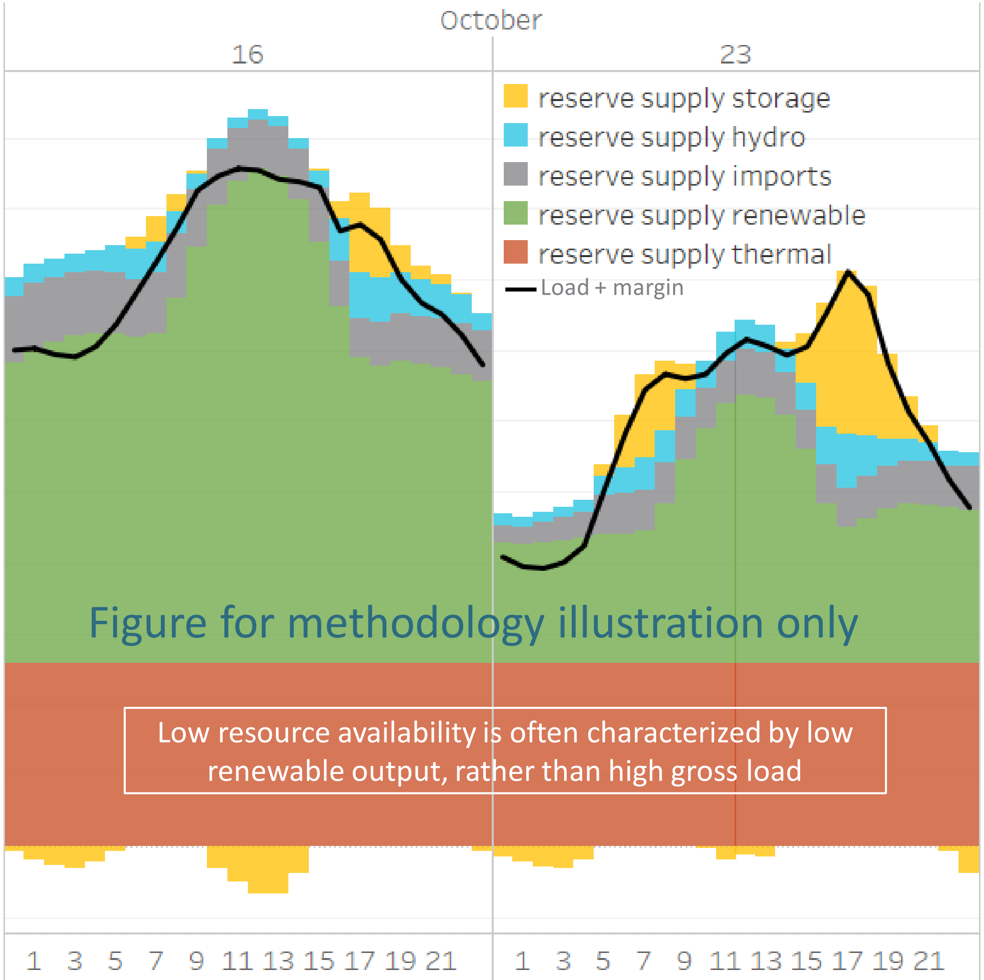
### Future System Reliability Assessment



# How Does RIO Approach Reliability?

- Reliability is assessed across all modeled hours with explicit accounting for:
  - Demand side variations – higher gross load than sampled
  - Supply side availability – outage rates, renewable resource availability, energy availability risk, single largest contingencies
- Multiple years used in day sampling adds robustness
- Advantage over pre-computed reliability assessments because it accommodates changing load shapes and growing flexible load
  - Any pre-computed reliability assessment implicitly assumes a static load shape, which is not a realistic assumption
- No economic capacity expansion model can substitute fully for a LOLP study, but different models offer different levels of rigor

## Hourly Reliability Snapshot



# Clean Energy Standard and Emissions Targets

What clean electricity and emissions policies are we modeling?

# West-Wide RPS/CES Targets

| | Targets | | | | | | |
|---|---|---|---|---|---|---|---|
| **Year** | **2020** | **2025** | **2030** | **2035** | **2040** | **2045** | **2050** |
| **Arizona** | 6% | 15% | 50%* | | 75% | | 100% |
| **California** | 33% | | 60% | | 87% | 100% | 100% |
| **Colorado** | 30% | | 30% | | 30% | | 30% |
| **Idaho** | None | | | | | | |
| **Montana** | 15% | 15% | 15% | 15% | 15% | 15% | 15% |
| **Nevada** | 22% | 25% | 50% | | 75% | | 100% |
| **New Mexico** | 20% | | 50% | | 80% | 100% | 100% |
| **Oregon** | 20% | | 80% | | | 100% | 100% |
| **Utah** | 0% | 20% | 20% | 20% | 20% | 20% | 20% |
| **Washington** | 12% | | 80% | | | 100% | 100% |
| **Wyoming** | None | | | | | | |

Arizona targets based on Net-Zero Plan approved by ACC
*50% by 2032 in Arizona

Assumed Oregon targets mirror Washington's Clean Energy Transformation Act (CETA)

# OR Policy Mirror of WA Clean Energy Transformation Act (CETA)

## CETA Requirements

- 2025: Eliminate coal-fired electricity from state portfolios
- 2030: Carbon neutral electricity, >80% clean electricity with up to 20% of load met with alternative compliance:
  - Alternative compliance payment
  - Unbundled renewable energy certificates, including thermal RECs
  - Energy transformation projects
  - Spokane municipal solid waste incinerator, if results in net GHG reduction
- 2045: 100% renewable/non-emitting, with no provision for offsets

## CETA Implementation in the Model*

- 2025: Eliminate all OR coal electricity sales
- 2030: Constrain delivered electricity generation serving OR loads to be 80% or more from clean sources
  - Accounting on retail sales rather than production, i.e., losses are not included
- 2030: Constrain the remaining 20% to come from non-delivered RECs
  - Linear transition to 100% delivered clean energy by 2045
- 2045: 100% delivered clean electricity
  - Accounting on all electricity production for in state consumption, i.e., losses are included
  - Fossil generation can supply out-of-state load

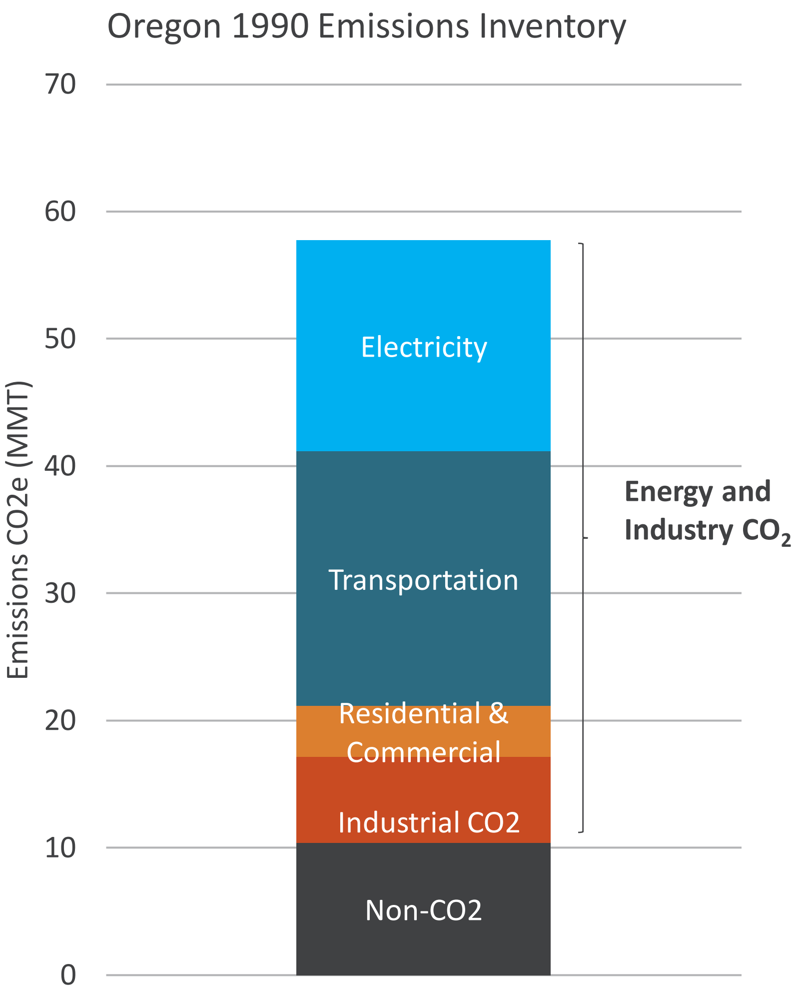
*Model assumptions on implementation developed prior to rulemaking and not indicative of final implementation

# Oregon Electricity Proposal

Additional scenario looking at Oregon proposal

- 80% electricity emissions reductions below baseline by 2030
- 90% electricity emissions reductions below baseline by 2035
- 100% clean electricity by 2040
- Baseline set using 2010, 2011, 2012 average electricity emissions from Oregon DEQ emissions tracking

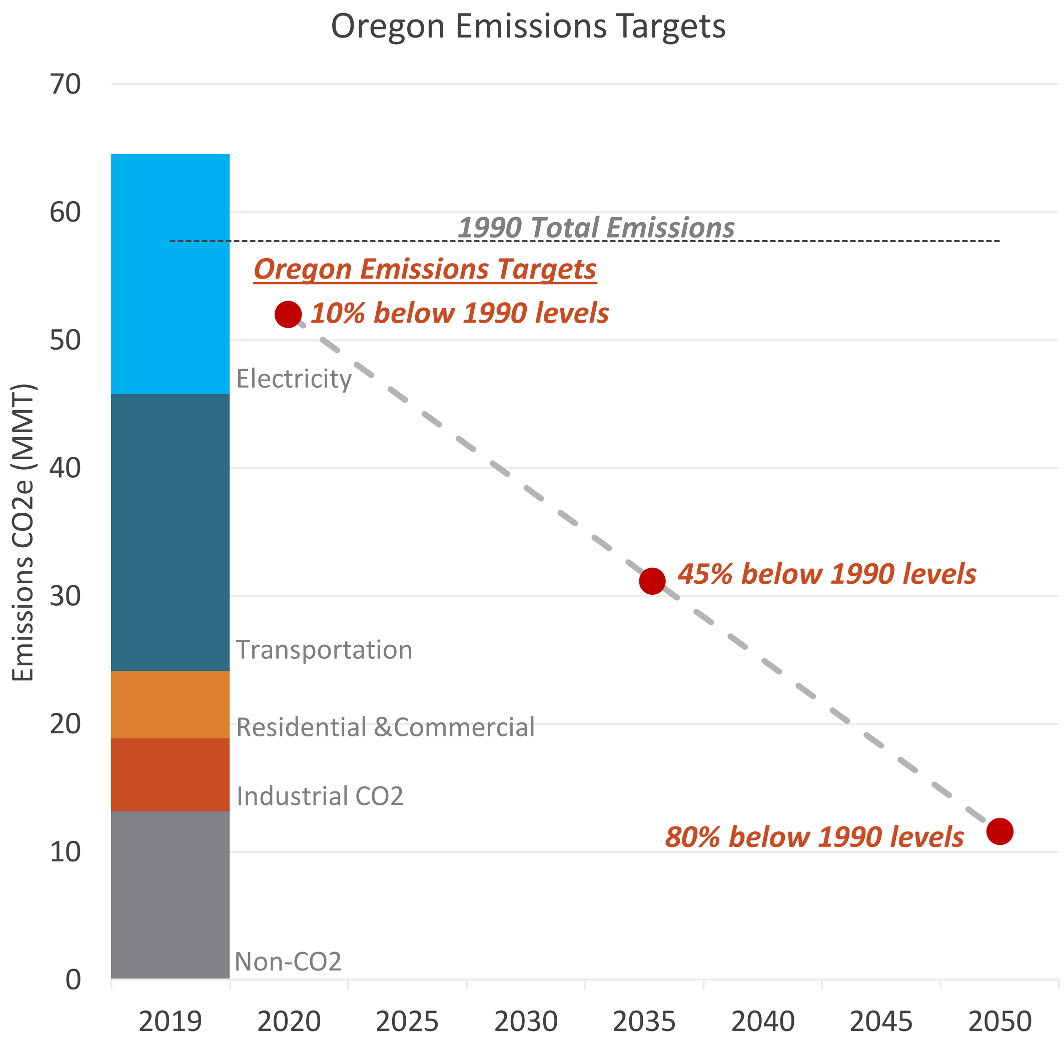
# Economy Wide Emissions Targets Set Based on the State's 1990 GHG Footprint




- Oregon's 1990 GHG emissions footprint was **57.7 million metric tons**
- Energy and industry related $CO_2$ emissions represent ~82% of all emissions
  - $CO_2$ emissions from **electricity generation** represent 29% of total emissions
  - Transportation (35%), Residential & Commercial (7%), and Industrial CO2 (12%) make up the remainder of energy and industry related $CO_2$ emissions
  - Non-$CO_2$ emissions (18%) make up the remainder

**Notes**: Industrial $CO_2$ includes industrial process emissions not from fuel combustion; non-$CO_2$ emissions includes agriculture, waste management, and industrial non-CO2 emissions

# Oregon Emissions Targets




- Oregon established economy-wide emissions goals of 10% below 1990 levels in 2020 and 75% below 1990 levels in 2050
- EO. 20-04 updated these to 45% below 1990 levels by 2035 and 80% below 1990 levels in 2050
- Assumes that non-$CO_2$ emissions are reduced by 80% by 2050 through a combination of emission reductions and land sink measures
  - **This leaves target of 80% in 2050 for energy and industry**

# West-Wide Emissions Targets for Study

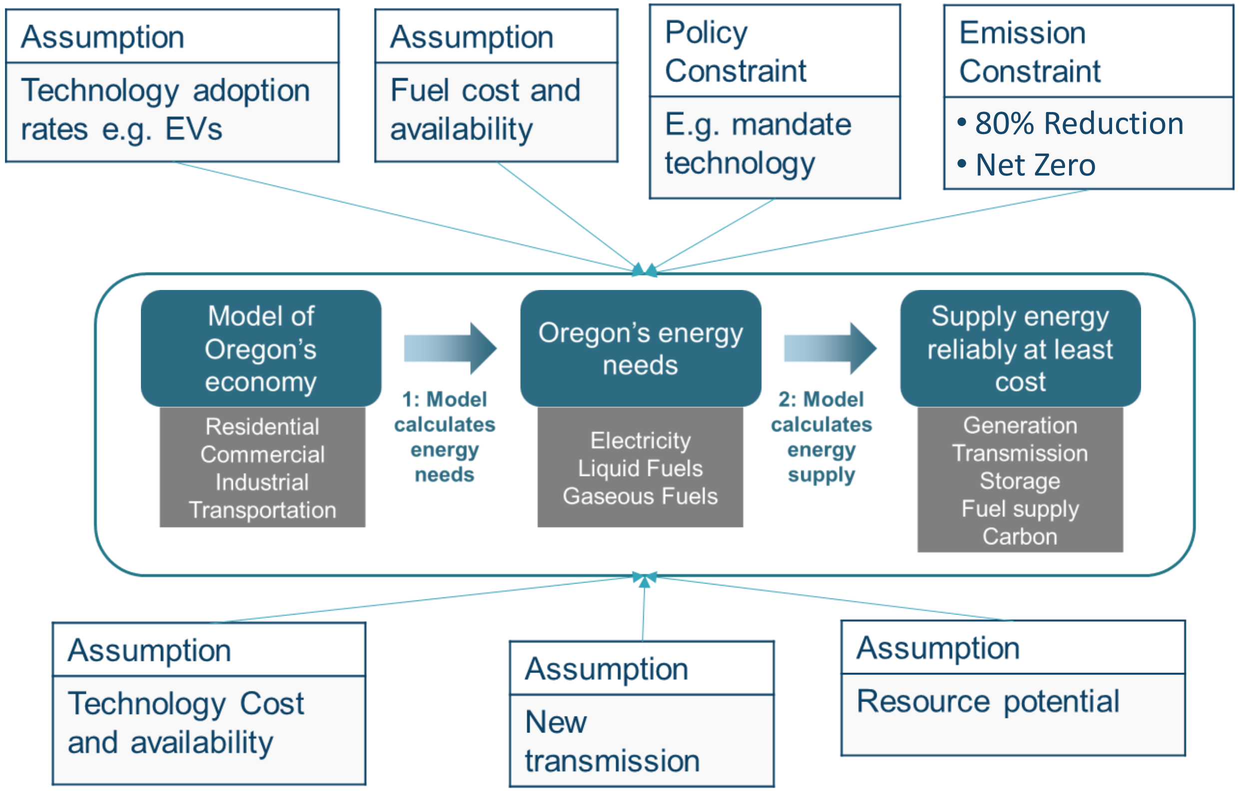
Two emissions targets for Oregon investigated in decarbonization scenarios

| (MMT) | 80x50 Oregon Emissions Target | | | | | | | 100x50 Oregon Emissions Target | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
| Arizona | | | 60 | | 34.4 | | 8.8 | | | 60 | | 30 | | 0 |
| California | 340 | | 213 | | 66 | -7.5 | -7.5 | 340 | | 213 | | 66 | -7.5 | -7.5 |
| Colorado | 95 | | 47 | | 23.2 | | -0.6 | 95 | | 47 | | 23.2 | | -0.6 |
| Idaho | 25 | | 14.1 | | 4.3 | | 2.1 | 25 | | 14.1 | | 4.3 | | 0 |
| Montana | 25 | | 15.6 | | 5.4 | | 2.6 | 25 | | 15.6 | | 5.4 | | 0 |
| Nevada | 45 | | 26.7 | | 9.1 | | 0.3 | 45 | | 26.7 | | 9.1 | | 0.3 |
| New Mexico | 60 | | 30.5 | | 10.2 | | 0 | 60 | | 30.5 | | 10.2 | | 0 |
| Oregon | 42.6 | | 31.6 | 26.0 | 20.5 | 15.0 | 9.5 | 42.6 | | 31.6 | 26.0 | 17.3 | 8.7 | 0 |
| Utah | | | 41.3 | | 24.4 | | 7.6 | | | 41.3 | | 20.7 | | 0 |
| Washington | 75.3 | | 40.1 | | 22.3 | | 0 | 75.3 | | 40.1 | | 22.3 | | 0 |
| Wyoming | | | 43 | | 25.5 | | 7.9 | | | 43 | | 21.5 | | 0 |

- Reference Case assumes no Oregon target, but other states achieve their emissions targets
- Targets above for Energy and Industry emissions (assumes measures are taken to reduce non-$CO_2$ emissions to meet overall emissions goals)

# Scenario Development

# Scenario Development: Investigate State Objectives




- Examine technical and economic implications of accelerating decarbonization in Oregon
- Translate state objectives, potential policy pathways, and uncertainties into constrained scenarios
- Understanding the tradeoffs
  - How much does one pathway cost versus another?
    - Counterpoint for policymakers and stakeholders
  - Provides a target for near-term policy and action design
- Understanding the uncertainties
  - How does an uncertain future impact state decisions?

# Scenario Descriptions

| Scenario | Summary | Key Question |
| --- | --- | --- |
| Reference | Business as usual | Assumes current CES policy is implemented and no emissions targets anywhere in the West. |
| 80x50 | Investigates the challenge of achieving an 80x50 emissions target and 100% CES | What investments are needed and how much would it cost to meet the 80x50 target if the demand side aggressively electrifies and energy supply options are relatively unconstrained? |
| 80x50 No New Gas (West-wide scenario) | Investigates what the West would do differently if new gas build was not permitted (allows extension of existing gas) | What is the cost and investment impact of preventing new gas build? What alternative investments would be needed in place of gas? |
| 80x50 Electricity Proposal | Investigates the impact of Oregon's electricity proposal | How does the Oregon electricity proposal impact the results versus the CETA-like policy assumed in the other scenarios? |
| 100x50 | Investigates the challenge of achieving an 100x50 emissions target and 100% CES | What investments are needed and how much would it cost to reach a more stringent 100x50 target? |
| 100x50 In-State Only | Investigates the impact of restricting Oregon to serving future energy needs with in-state only resources | What alternative investments in in-state resources would Oregon make if energy must come from in the state? Scenario includes resources located physically within Oregon as in-state. |
| 100x50 Low Transformation | Investigates how slower electrification and efficiency gains impact investments | How does reduced electrification and efficiency impact total costs and investment strategy? |

# Scenario Assumptions

## Set of 7 scenarios

<table>
<tr><th>Scenario Assumptions</th><th>1. Reference</th><th>2. 80x50</th><th>3. 80x50 No New Gas</th><th>4. 80x50 Electricity Proposal</th><th>5. 100x50</th><th>5. 100x50 In-State Only</th><th>6. 100x50 Low Transformation</th></tr>
<tr><td>Clean Electricity Policy</td><td>None</td><td colspan="2">100% clean electricity by 2045: Policy like Washington CETA</td><td>Emissions reductions: 80% by 2030, 90% by 2035, 100% by 2040</td><td colspan="3">100% clean electricity by 2045: Policy like Washington CETA</td></tr>
<tr><td>Economy-Wide GHG Policy</td><td>None</td><td colspan="3">45% by 2035, 80% by 2050 (vs 1990)</td><td colspan="3">45% by 2035, 100% by 2050 (vs 1990)</td></tr>
<tr><td>Clean Resource Qualification</td><td>None</td><td colspan="4">Constrained only by transmission limits</td><td>In-state resources only (includes existing in-state resources)</td><td>Constrained only by transmission limits</td></tr>
<tr><td>Buildings: Electrification</td><td>AEO</td><td colspan="5">Fully electrified appliance sales by 2035</td><td>75% electrified appliance sales by 2045</td></tr>
<tr><td>Buildings: Energy Efficiency</td><td>AEO</td><td colspan="5">Sales of high efficiency tech: 100% in 2035</td><td>75% electrified appliance sales by 2045</td></tr>
<tr><td>Transportation: Light-Duty Vehicles</td><td>AEO</td><td colspan="5">100% electric sales by 2035</td><td>15-year delay to full electric sales by 2050</td></tr>
<tr><td>Transportation: Freight Trucks</td><td>AEO</td><td colspan="5">HDV long-haul: 50% electric, 50% hydrogen sales by 2045. HDV short-haul: 100% electric sales by 2045. MDV: 100% electric sales by 2045</td><td>Sales target delay to 2050</td></tr>
<tr><td>Industry</td><td>AEO</td><td colspan="5">Generic efficiency improvements over Reference of 1% a year; fuel switching measures; 75% decrease in refining and mining to reflect reduced demand</td><td>Efficiency: 0.5% a year, 10-year delay in fuel switching measures</td></tr>
<tr><td>Resource Availability</td><td colspan="2">Same as 100x50</td><td>No West gas build (excl. extensions)</td><td colspan="4">NREL resource potential; 6 GW of new transmission potential per path; 2x REEDS Tx Costs; SMRs not permitted. Keep co-gen online</td></tr>
<tr><td>Fuels</td><td colspan="7">AEO Reference fuel prices; no sequestration potential; clean fuels have zero emissions associated with them, so sequestration credit is left in state of origin</td></tr>
</table>

# Results: Demand Side

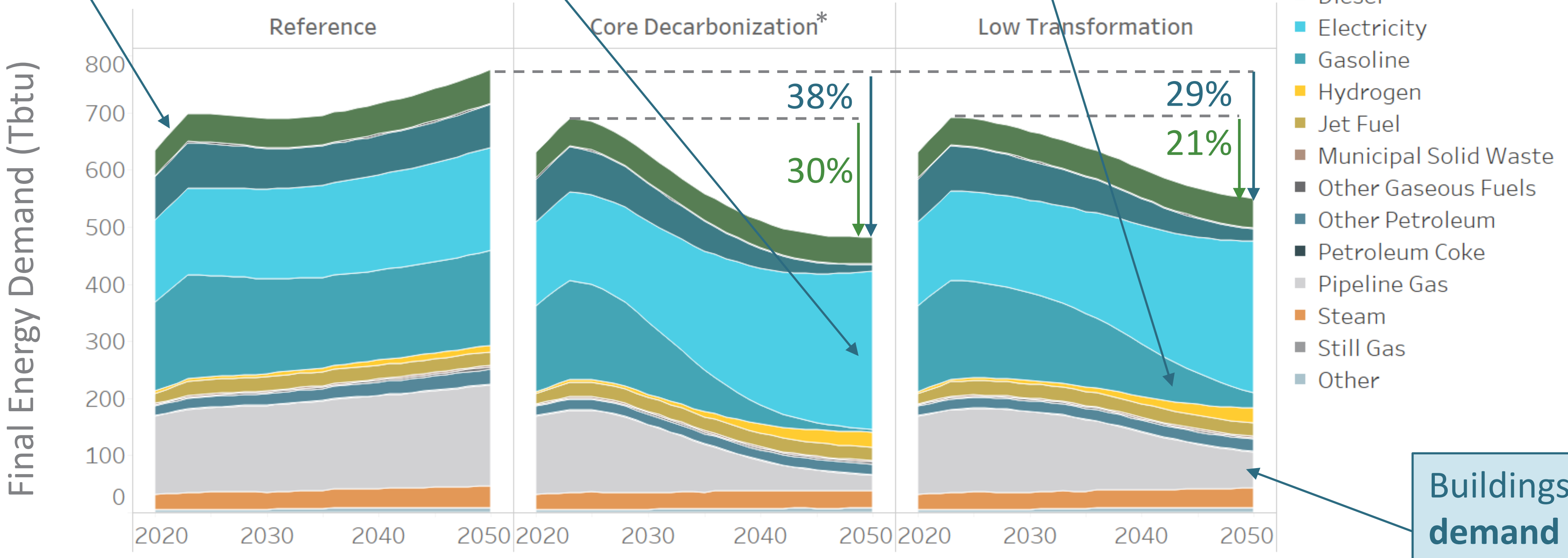
# Final Energy Demand

## Electrification and efficiency drive lower total energy demand

COVID: **10% drop in demand in 2020** due to COVID impact

Electrification: **90% growth in electricity sector** over 2020 levels, displacing fuels

Transport Fuels: **Slower demand reductions**

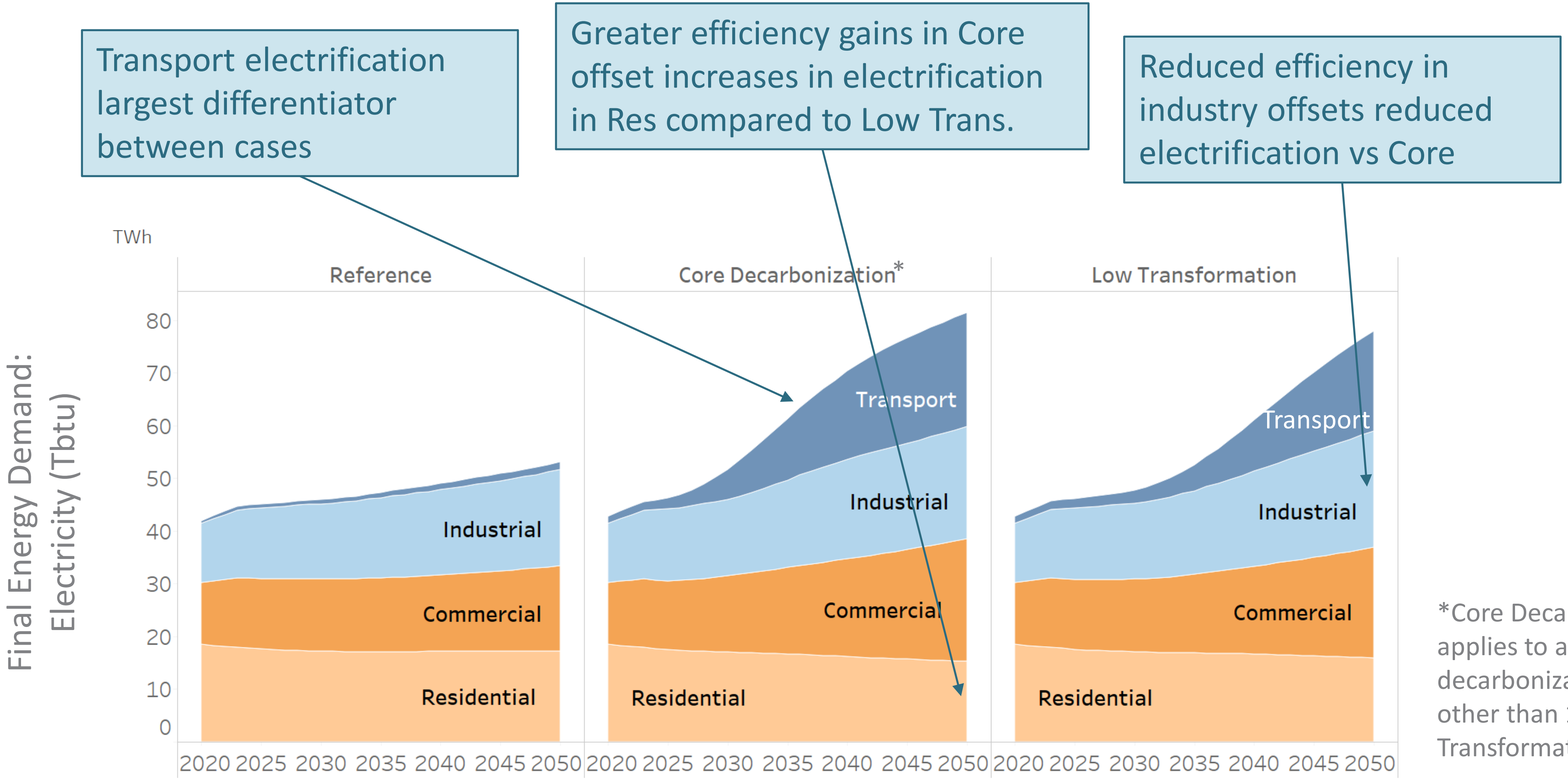



Buildings: **Higher demand for gas** due to less electrification

*Core Decarbonization applies to all decarbonization scenarios other than 100x50 Low Transformation

# Final Energy Demand: Electricity

Electricity use in decarbonization scenarios grows significantly

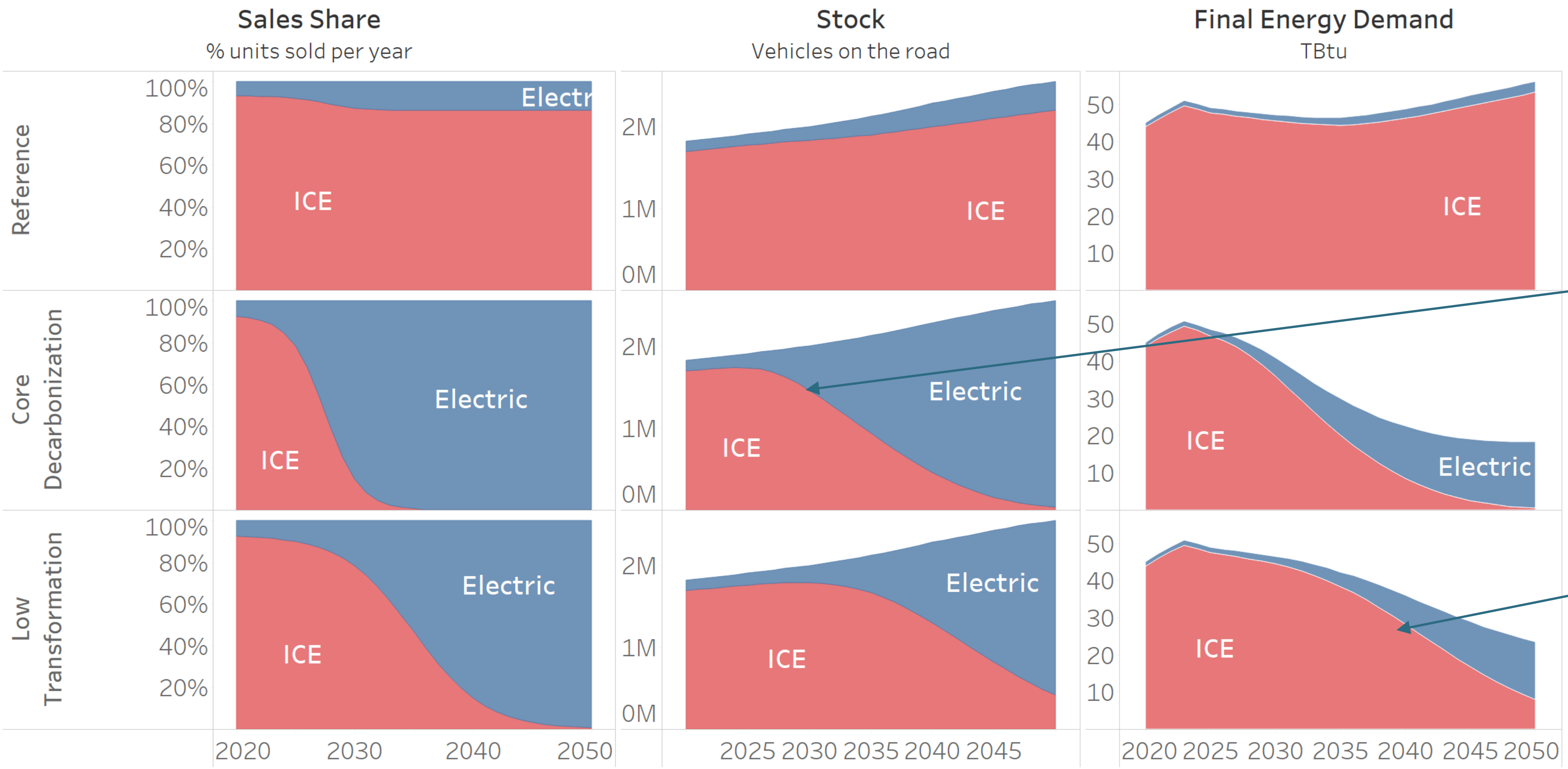



*Core Decarbonization applies to all decarbonization scenarios other than 100x50 Low Transformation

# Example Sector: Light-Duty Vehicles - BEVs are Key to Lower Energy Demands

Lower energy demands reduce the need for investment in clean energy technologies to meet OR targets

Projected Sales, Stock, and Final Energy Demand




73% of vehicles are ICE in 2030 in Core Decarbonization

Energy demand for fuels remains high in later years in Low Transformation



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# Results: Supply Side

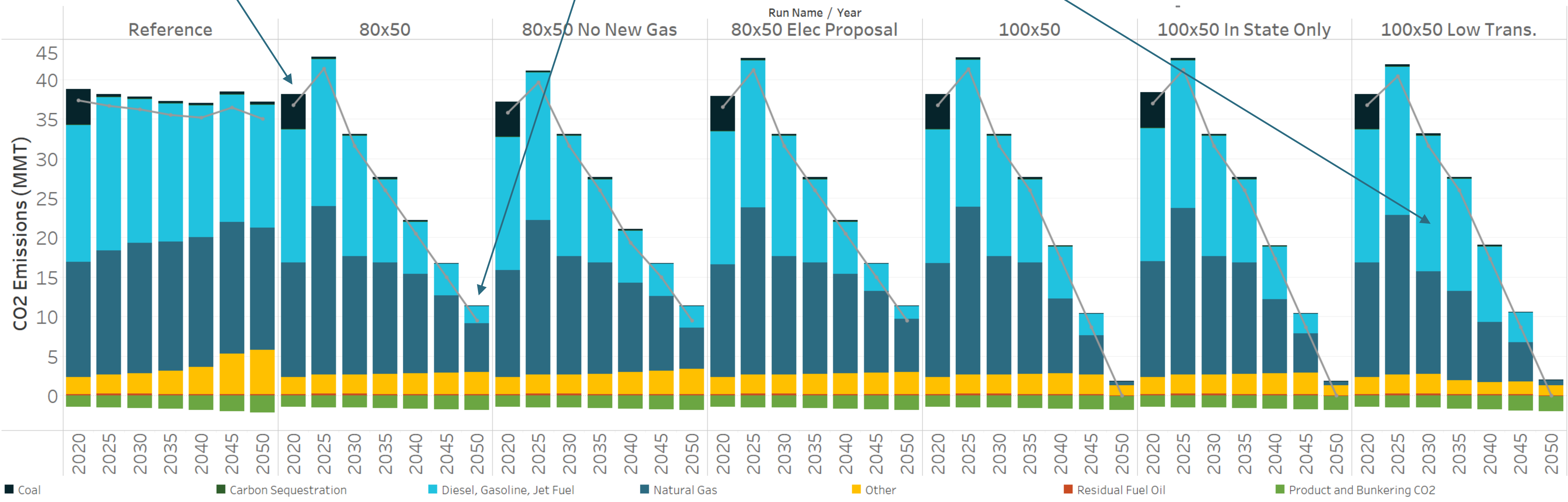
# Emissions

Still room for emissions by 2050 in 80x50

Lower emissions in 2020 due to COVID, and coal contracts not represented in the model

Natural gas is majority of emissions by 2050

Greater percentage of liquid fuels remaining in emissions in Low Transformation



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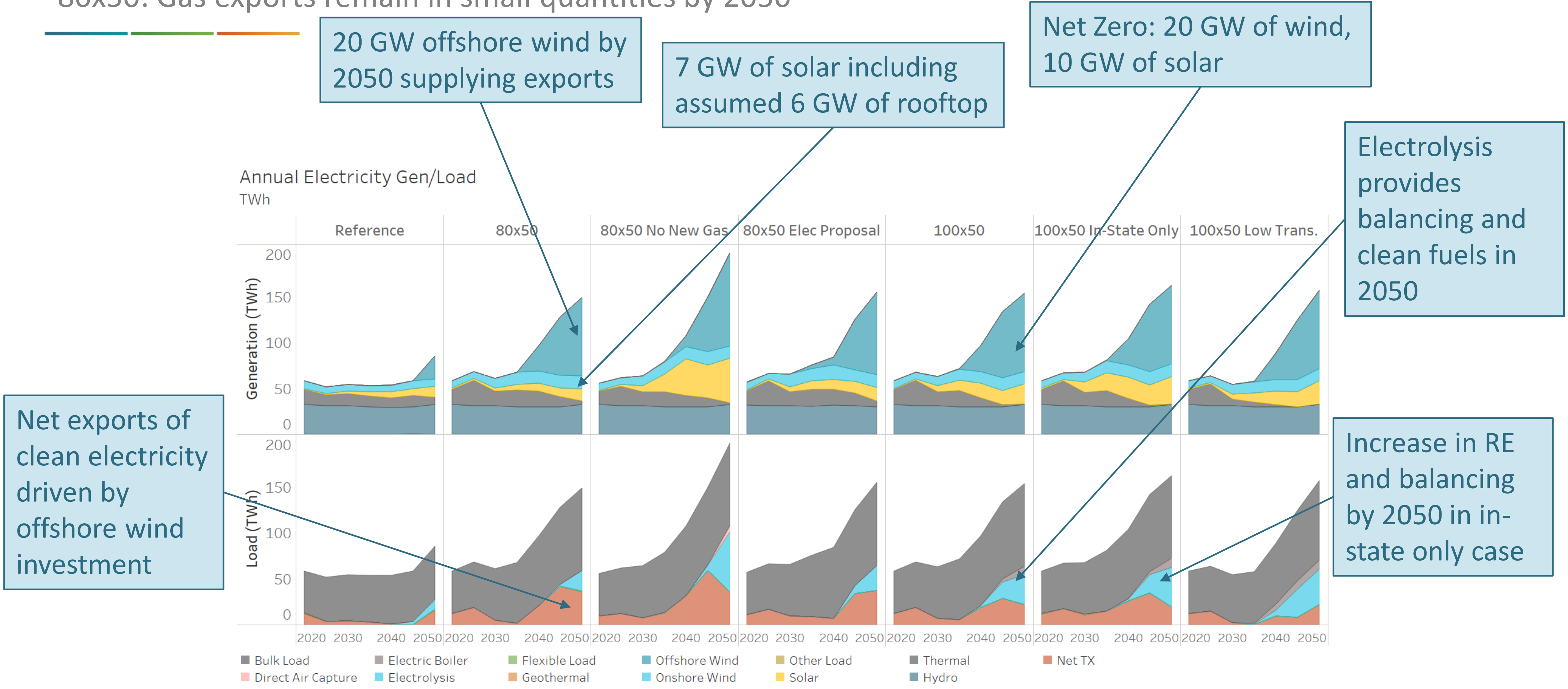
# Generation and Load

## 80x50: Gas exports remain in small quantities by 2050



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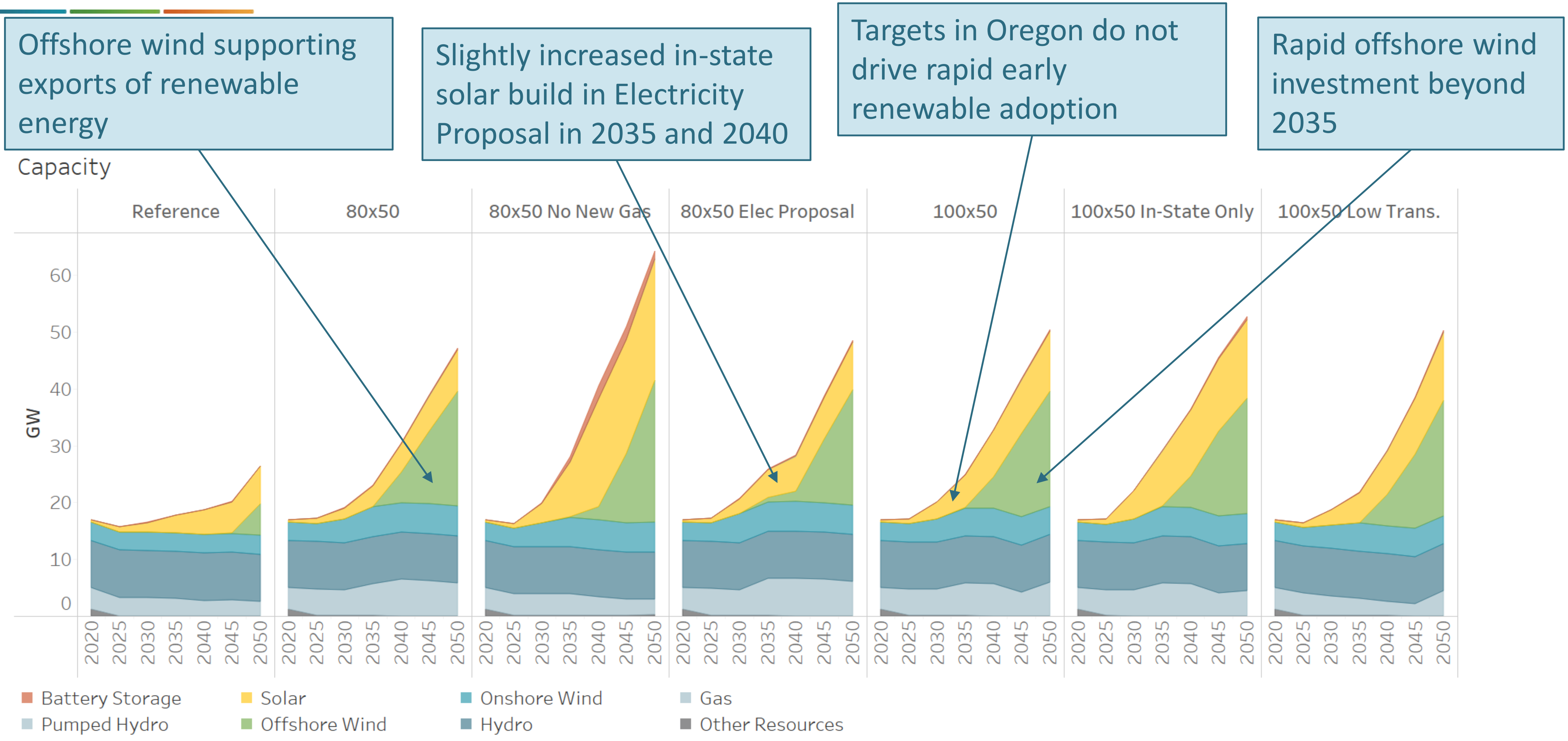
# Capacity

Modest renewable energy investment through 2030 with rapid offshore wind investment 2035 to 2050



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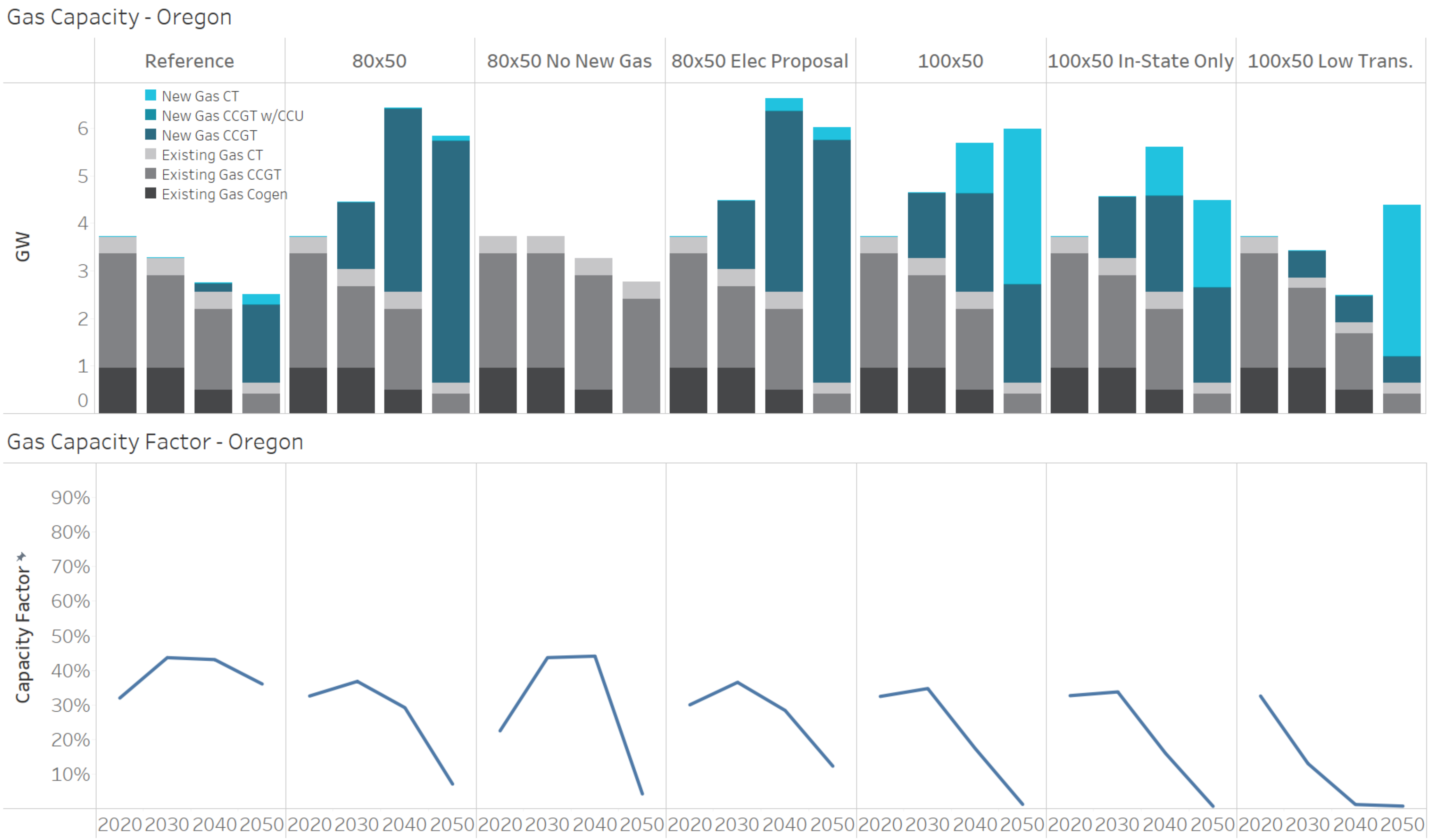
# Gas Capacity

Total gas capacity relatively consistent across years in most cases



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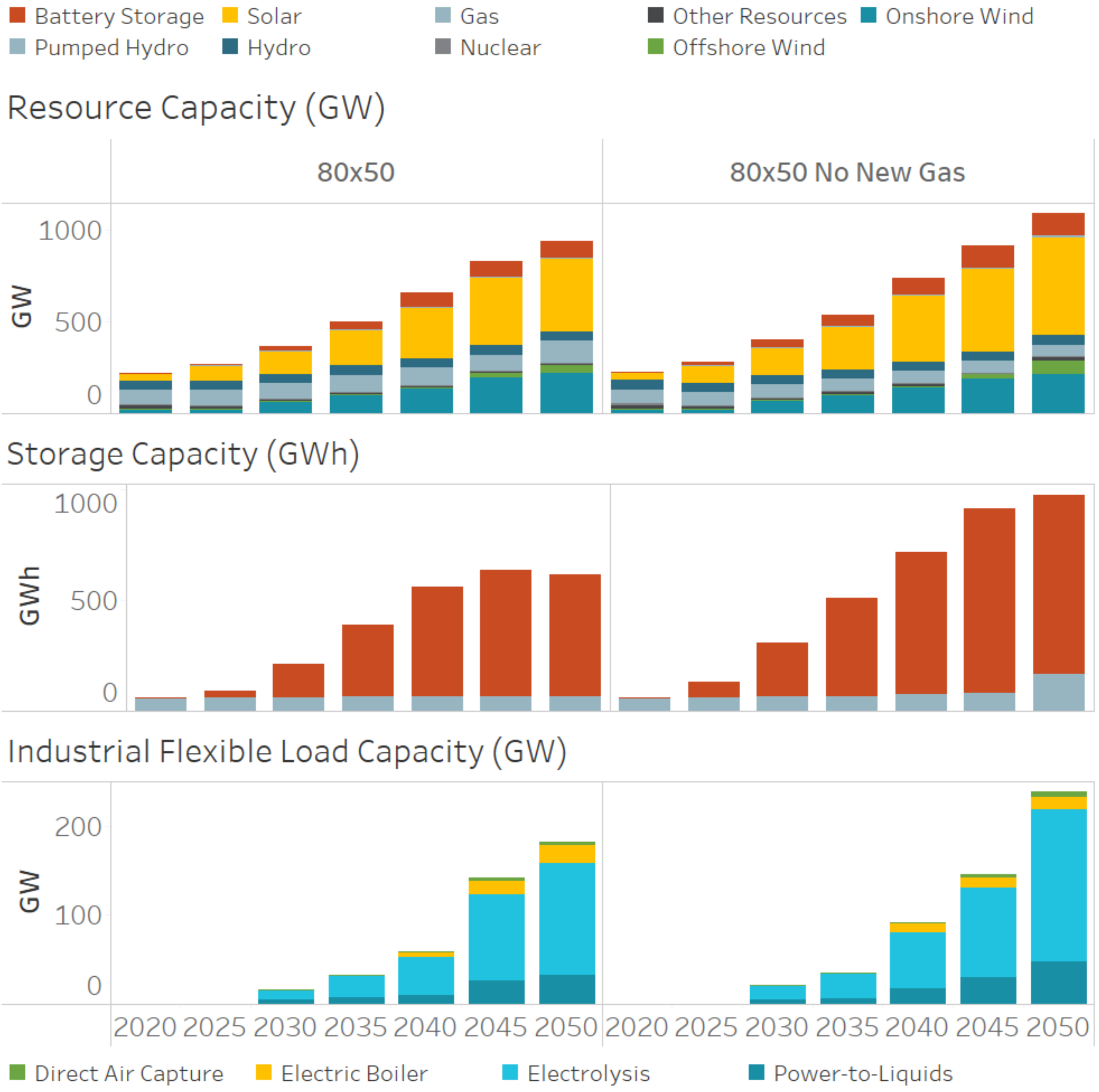
# 80x50 No New Gas

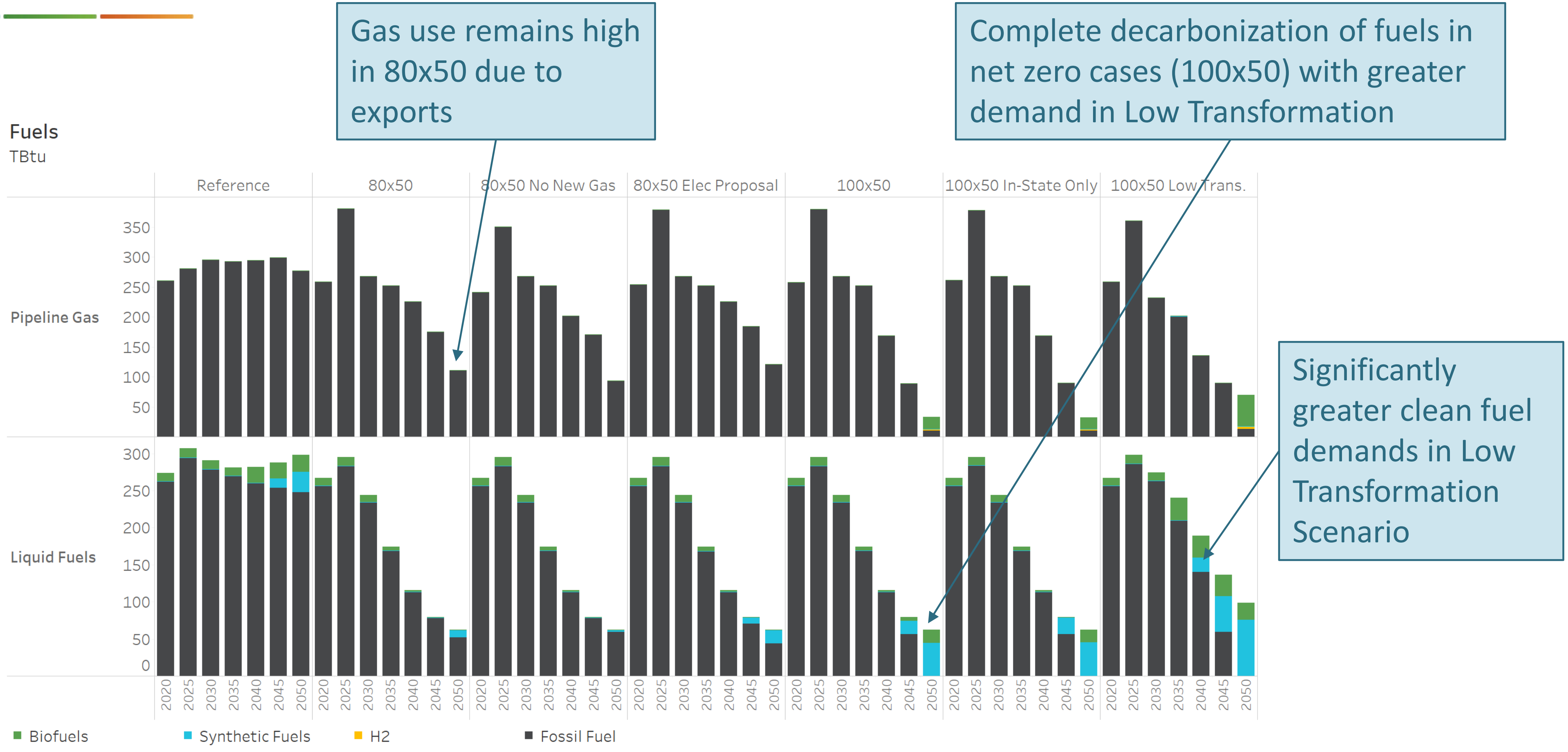
## West wide resource investments

- Limiting gas build impacts West-wide investments and operations
  - 46% less gas capacity in No New Gas scenario by 2050
- Shift to alternatives for system reliability
  - Increased renewables (21% by 2050)
  - Increased storage build (GW: 42%, GWh: 58% by 2050)
  - Increased flexible loads (31% by 2050)



# Major Fuels

Gas retained in the 80x50 using remaining emissions allowance. Decarbonized in 100x50.



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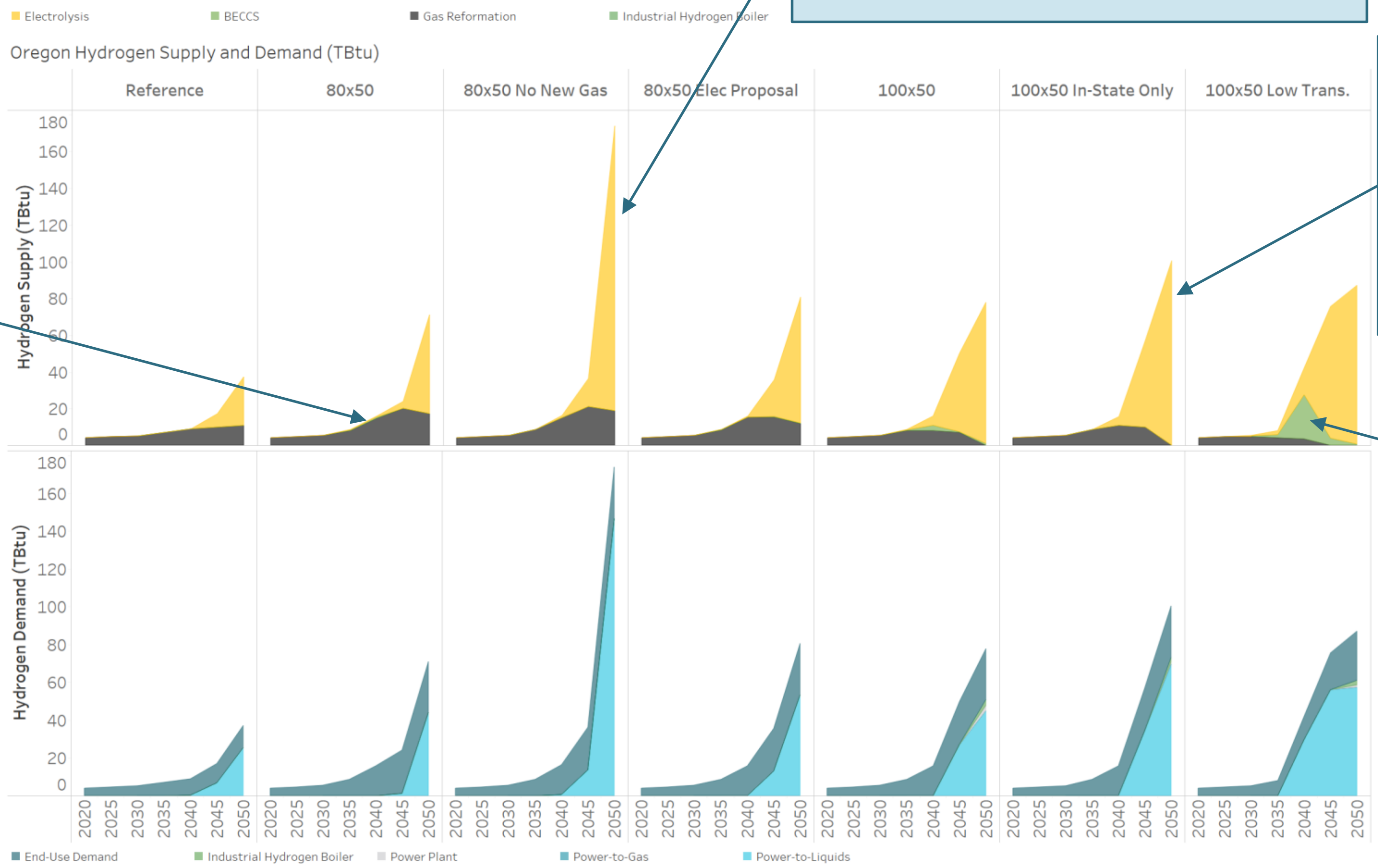
# Hydrogen Supply and Demand

Gas reformation remains in 80x50 to produce hydrogen for vehicles and other end uses

Greater balancing provided by flexible H2 production in No New Gas scenario




Increased electrolysis meeting higher in-state fuel demand in In-State Only scenario

Biomass more cost effective for earlier clean fuel demand in low transformation



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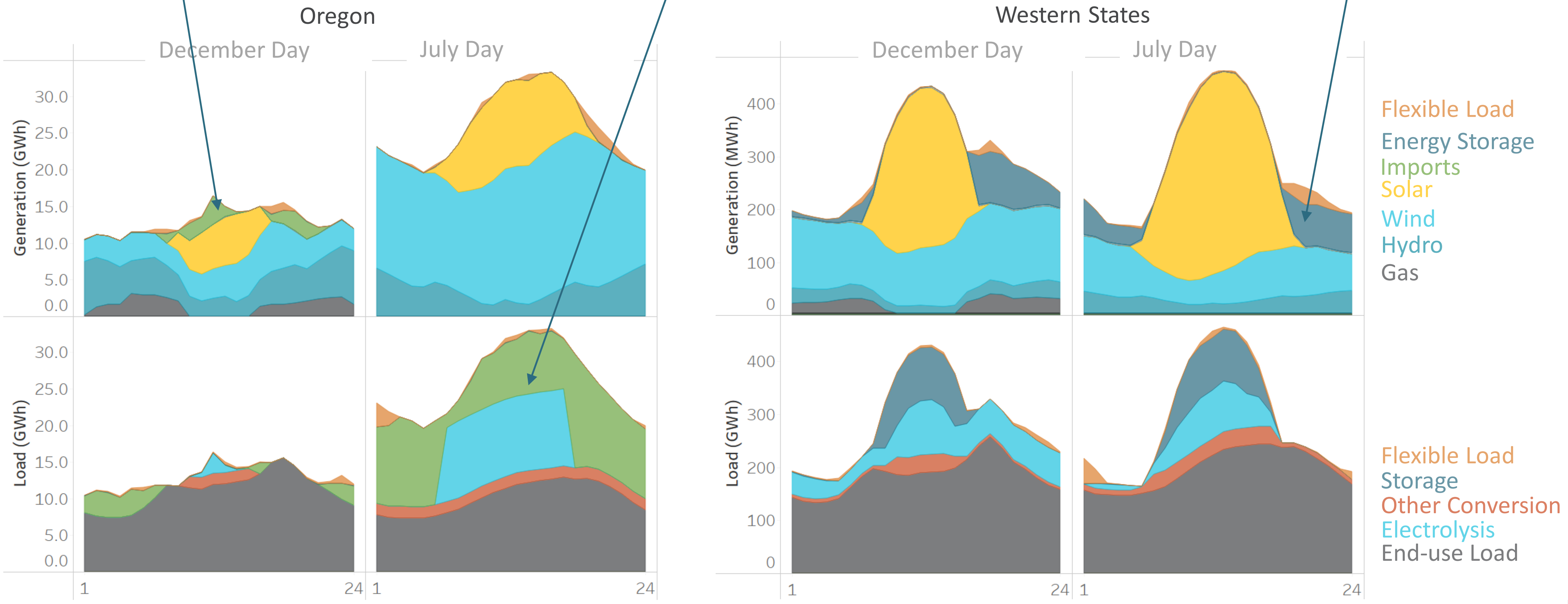
# Balancing the System: High Energy and Low Energy Days in 2050

## Oregon relies on imports/exports, hydro, and electrolysis to balance load

Constrained energy day in OR: March: flex loads, imports, and gas

Unconstrained energy day in July: exports and electrolysis

Significant storage build in the rest of the West helps balance diurnal solar shape





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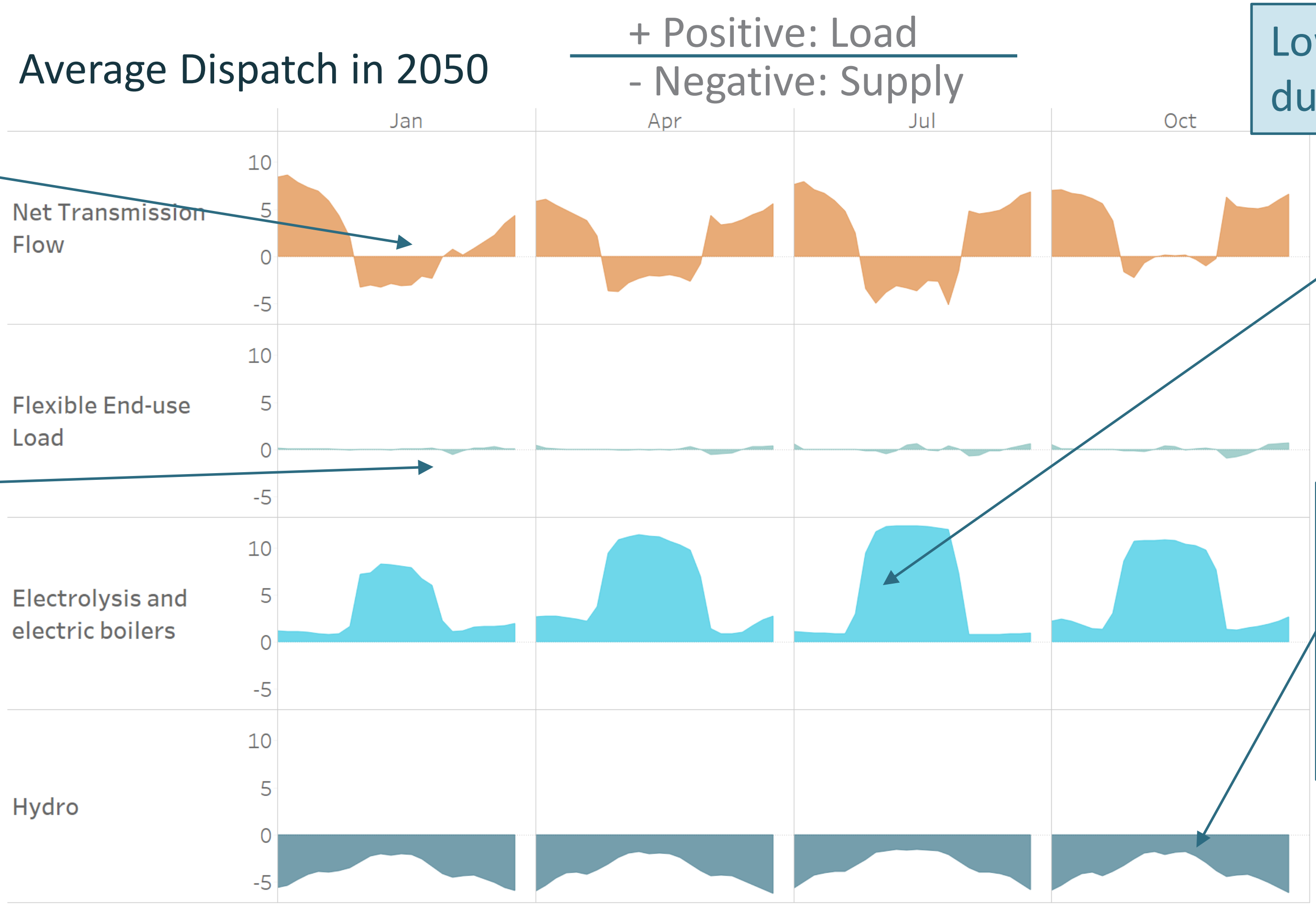
# Oregon’s Main Balancing Resources

Hydro, imports, electrolysis, and flexible loads are principal balancing resources in OR

Net transmission flow reflects resource mix in-state vs. out-of-state

Flexible loads drive down peak loads

Gas generation provides capacity towards reliability requirements but does not deliver energy to Oregon loads



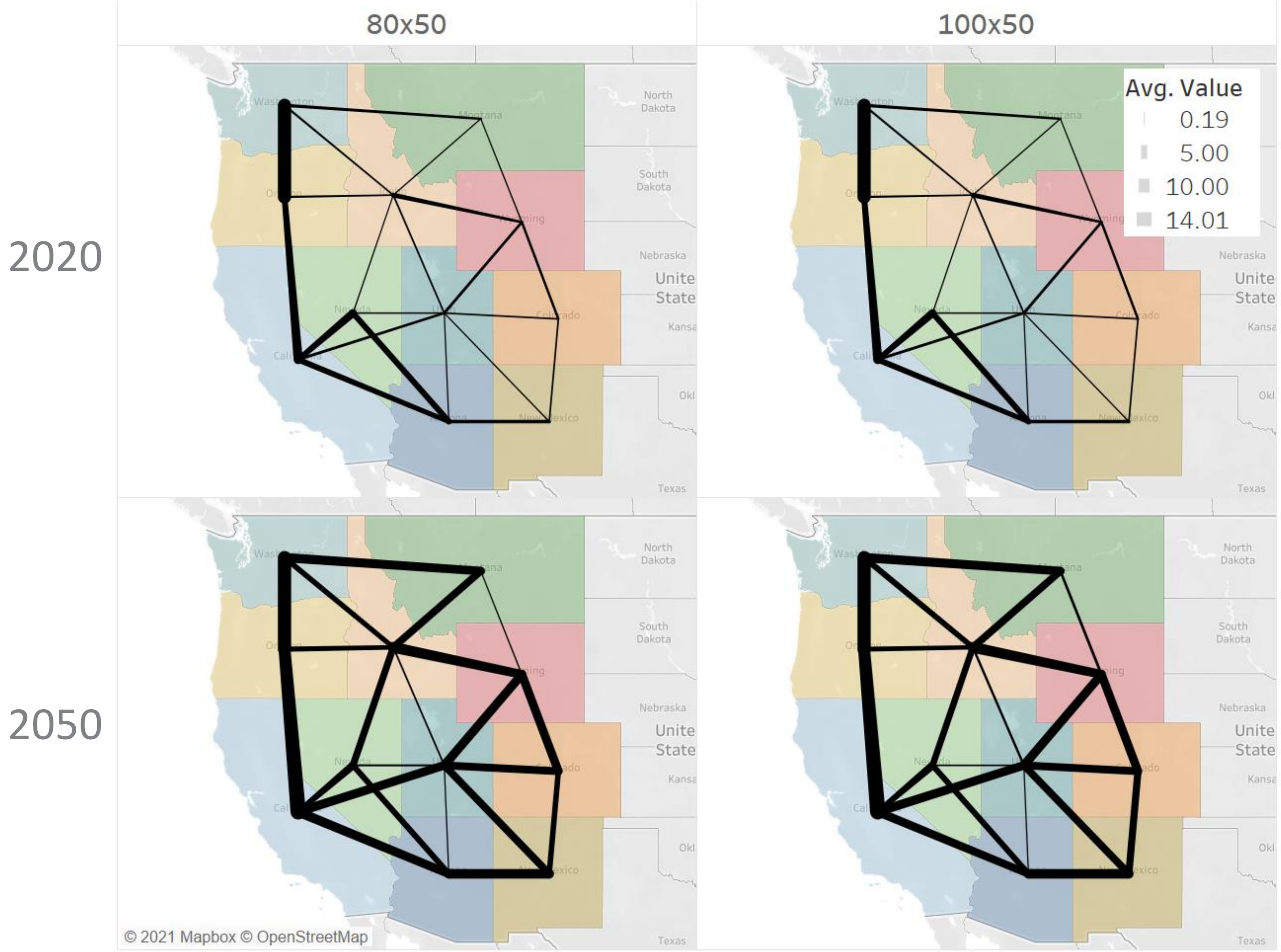

Lower summer electrolysis due to reduced imports

Hydro operated flexibly, adhering to historically observed minimum flow, ramp, and energy constraints

# Transmission Expansion – Western States

Oregon is transmission hub between other decarbonizing states

- Transmission expansion of up to 6 GW between states permitted in the model
  - Priced at 2x the NREL REEDS model transmission costs
- Significant strengthening of the entire Western grid in both 80 and 100x50
  - 6 GW to CA and 3.4 GW to ID in 100x50
- California and Washington driving east to west transmission flows
  - Taking advantage of low-cost wind and resource diversity





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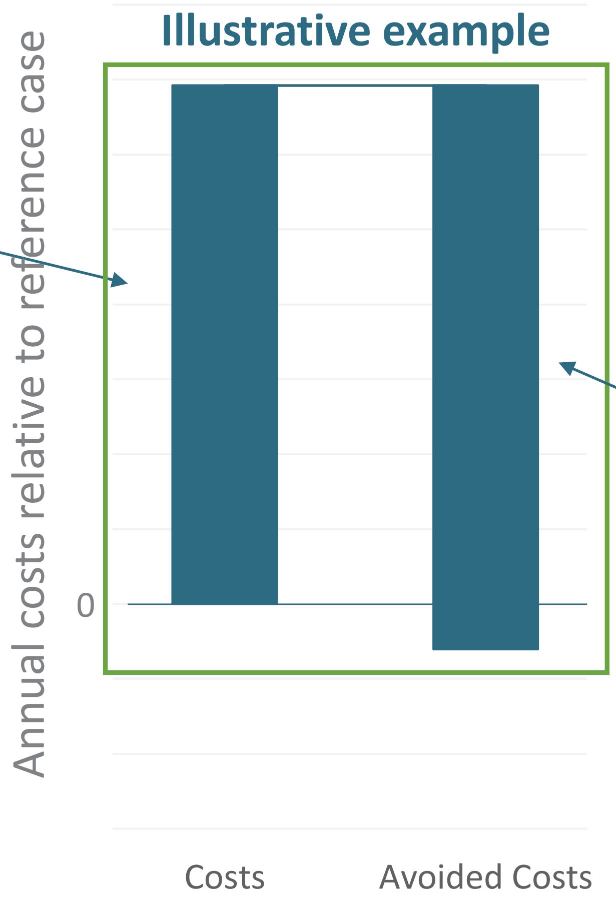
# Results: Costs

# Understanding the Costs of Decarbonization

Costs and benefits of Electrification Case relative Reference Case in 2050 shown

Increased costs relative to Reference Case:

- Demand side equipment
- Supply side equipment
- Operating costs

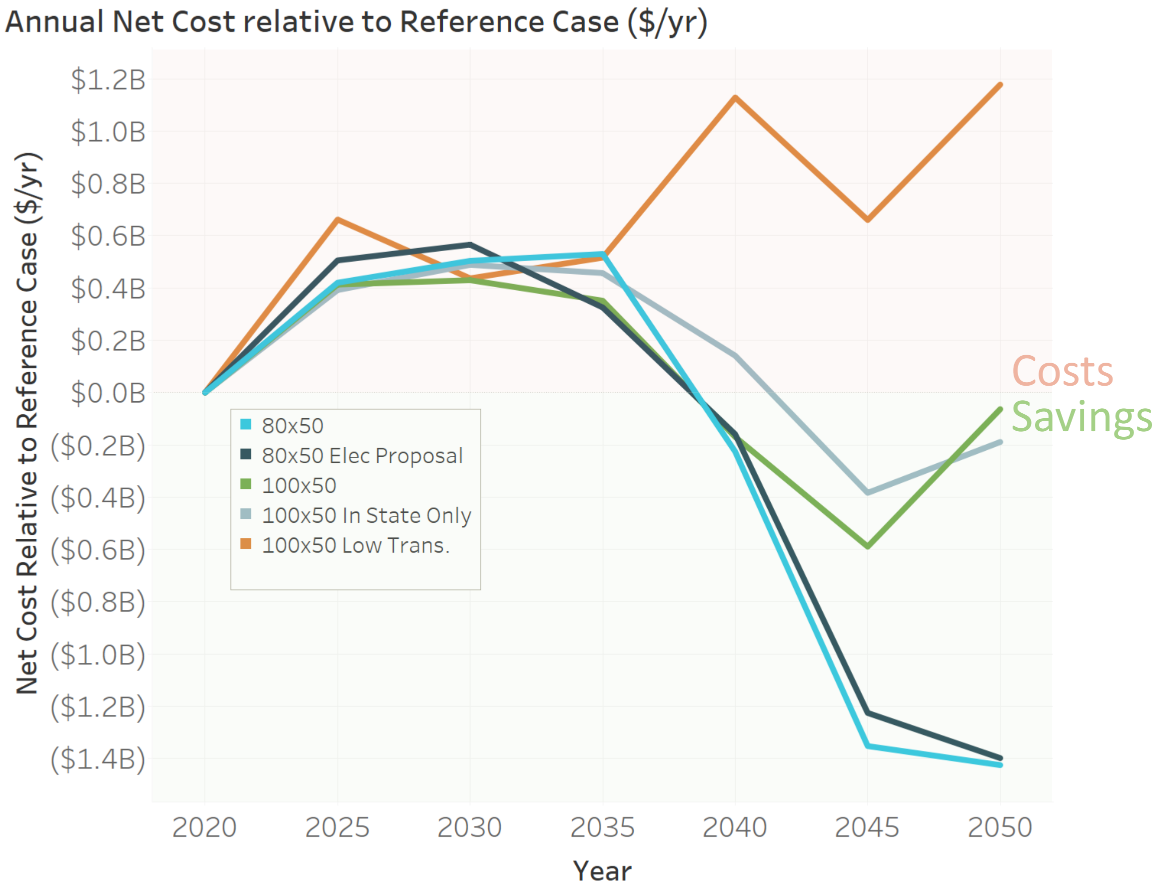



Results from decarbonization modeling include direct costs and avoided costs of decarbonization (reported in next slides)

Cost savings relative to Reference Case:
Avoided equipment and operating costs (predominantly fuel purchases)

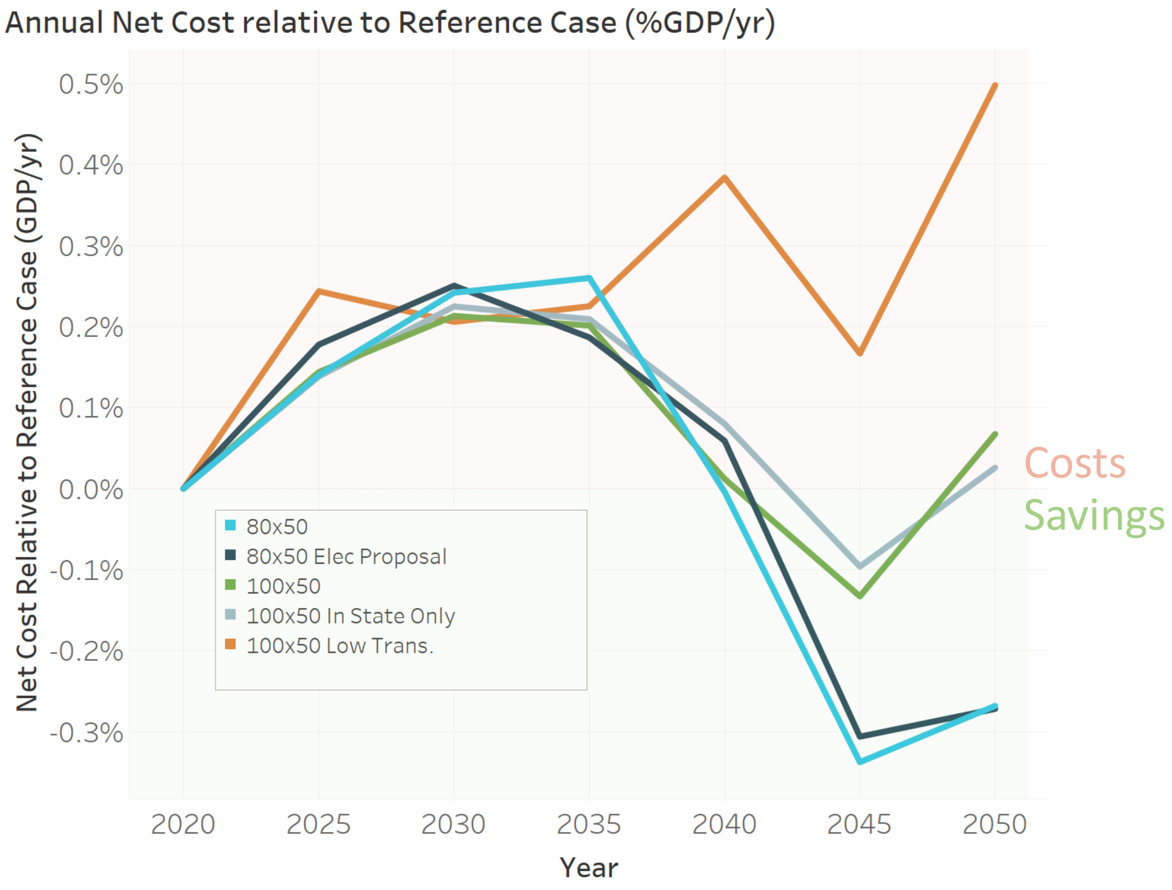
# Scenario Cost Comparison

- Increase in net cost versus the Reference Case through 2035
  - ~0.2% of GDP increase in 2030
- Similarities between scenarios through 2035
  - Targets are the same
- Additional investments needed in 100% vs. 80% scenarios beyond 2035
- Outlier: Low Transformation – significant cost increases over 100x50



# Scenario Cost Comparison GDP

- Additional investment in GDP terms is approximately 0.2% per year through 2035 across scenarios
- Spending decreases as technologies get cheaper in the future
- Lower cost transition compared to Washington
  - Meeting targets is easier with Oregon coal retirements
  - Valuable offshore wind resource



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# Cost Drivers

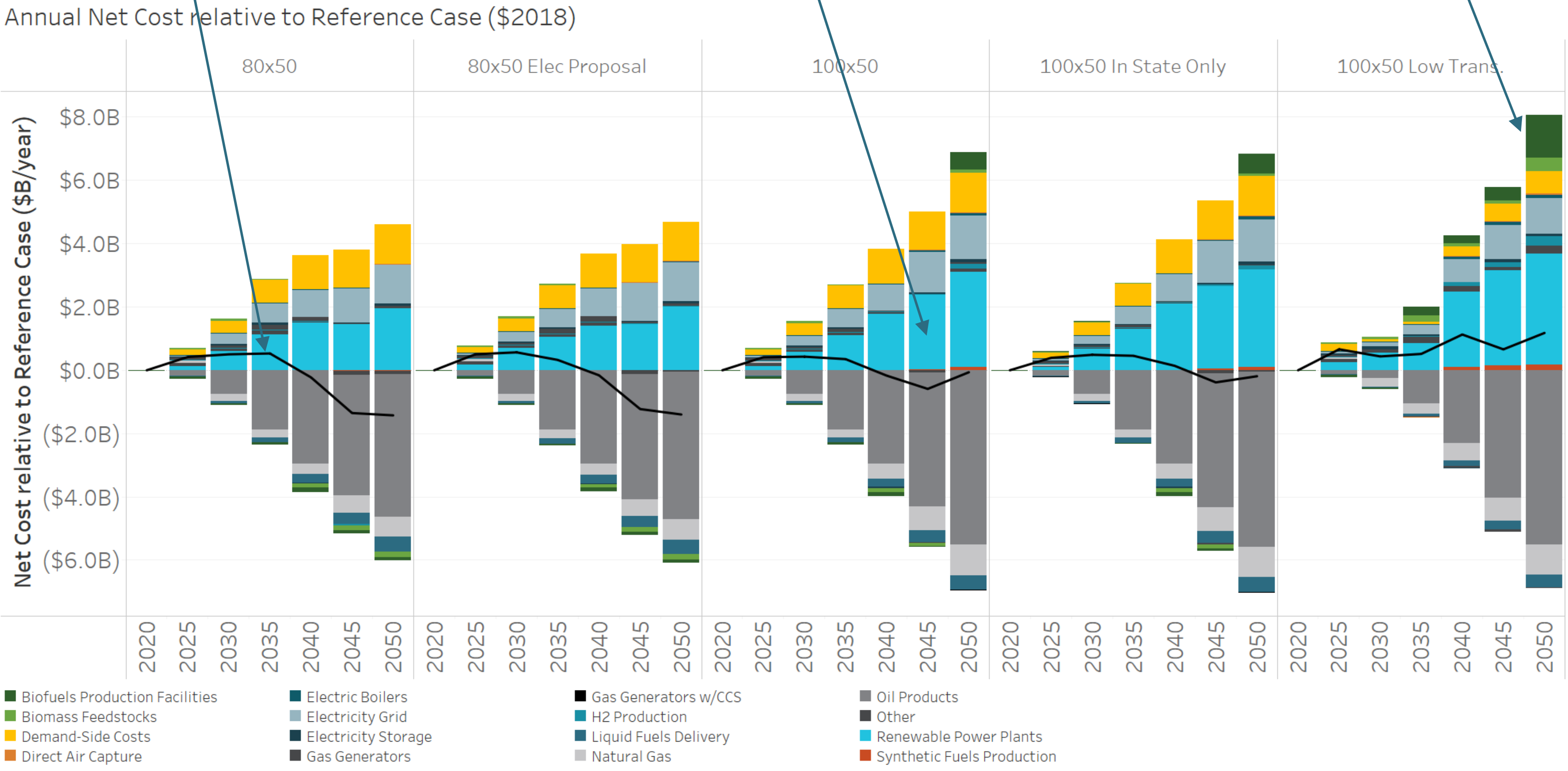
| Scenario | Average Net Cost (GDP/yr) Relative to Reference Scenario: | Cost Drivers |
|---|---|---|
| **80x50** | **0.0%** | Relatively low investment in clean energy technologies on the supply side through 2035 followed by investment beyond 2035 at lower prices for renewables control costs across all scenarios. |
| **80x50 Elec. Proposal** | **0.0%** | Minimal impact of the electricity proposal vs 80x50. Reaches cleanly delivered electricity in Oregon sooner. |
| **100x50** | **0.1%** | Follows the same investment trajectory as 80x50 through 2035, followed by additional investments in renewables to reach the 100x50 target. |
| **100x50 In State Only** | **0.1%** | Oregon is a large net exporter in later years of offshore wind energy. Still taking advantage of exports and backing off exports to balance the system. Repurposing Oregon energy production for in-state needs and building out additional hydrogen production for fuels. |
| **100x50 Low Transformation** | **0.3%** | Largest cost increase. Whereas other 100x50 scenarios show relatively little impact on Oregon costs, not electrifying end uses impacts costs significantly, costing between 0.4% and 0.5% of GDP per year between 2040 and 2050 |

# Net Cost Components

Early net costs driven by renewable energy and demand side investments

Later net benefits as forecasted costs of clean energy investments decrease

Additional clean fuels requirements in Low Transformation scenario driving cost increase



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# Net Present Value of Net Costs

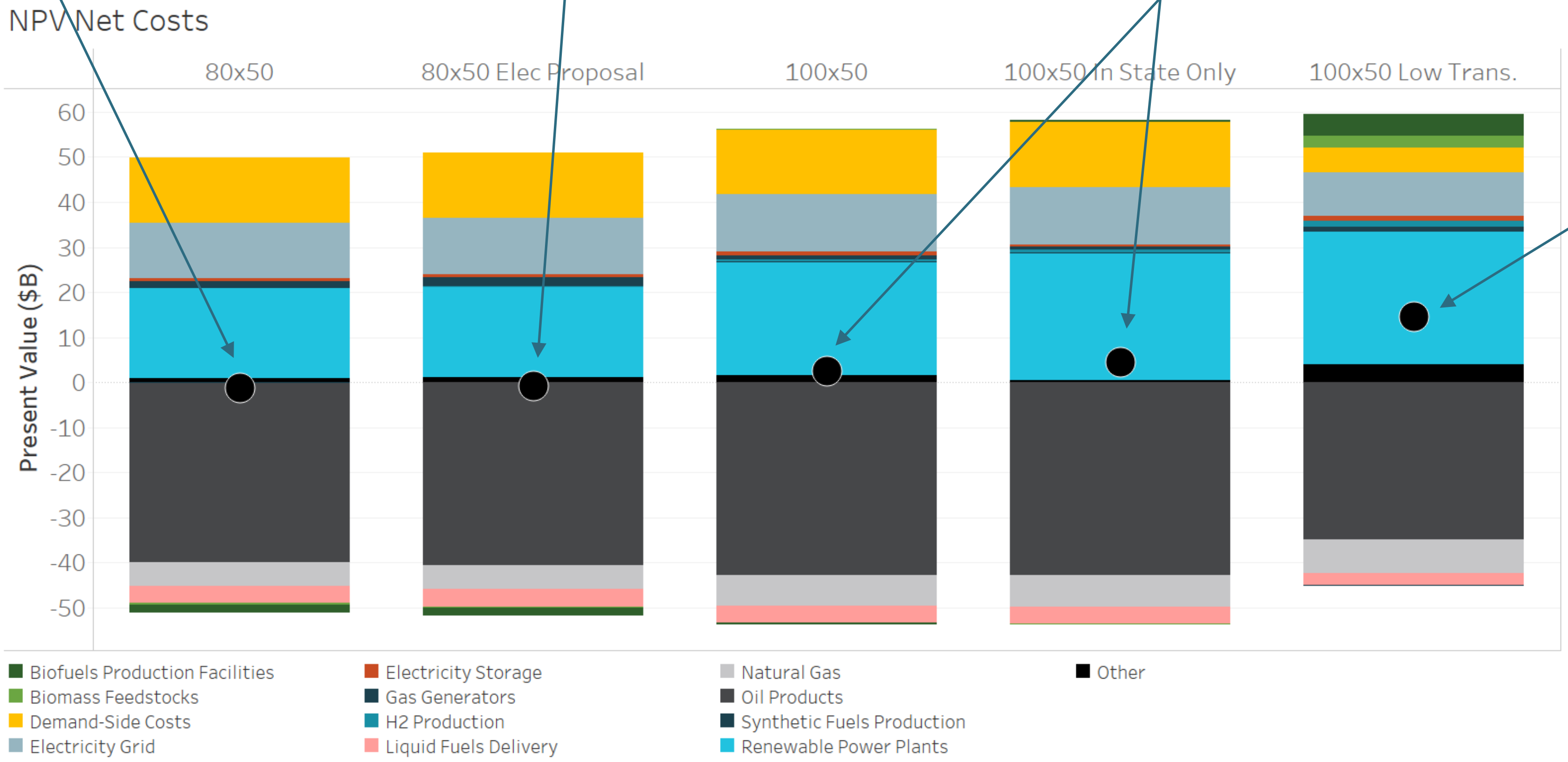
2% societal discount rate used

Net-zero impact of 80x50 on an NPV basis

Negligible impact of Electricity Proposal on costs vs. 80x50

In-State scenario similar in cost due to Oregon being a large exporter in 100x50

Increased investment in renewables and clean fuels and reduced savings from avoided fossil fuels



# 80x50 No New Gas

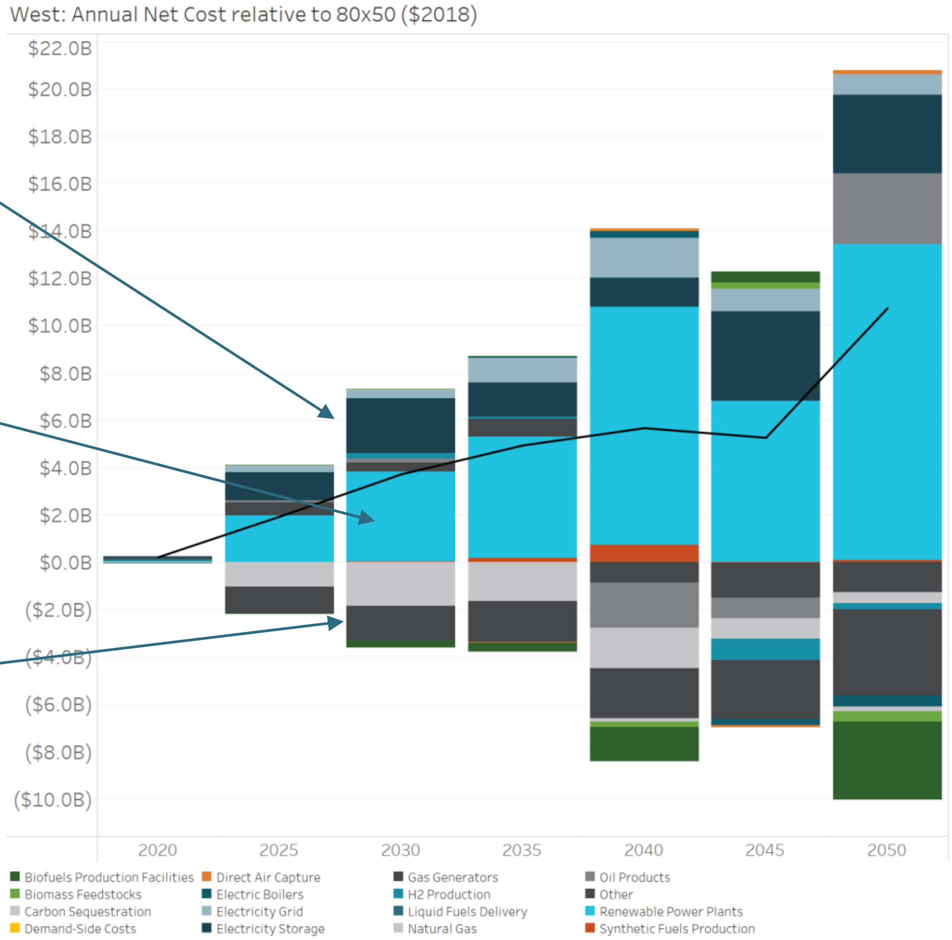
## West wide cost comparison

- Significant increases in spending around the West
  - Changing energy flows
  - Investments in storage
  - Additional renewables
- Allocation of reliability costs and benefits are a West-wide problem
  - Where resources that contribute to reliable grid operations are built and who pays for them is policy dependent

Increased storage investments

Increased renewable energy investments

Reduced spending on gas and gas capacity



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# Conclusions

# Key Takeaways

## Meeting the Targets

- 2030 emissions target (straight line between 2020 and 2035 targets) achieved by removing coal from electricity and replacing with new clean resources
  - The pace of action required to meet the 2030 target is lower than in neighboring states
- Meeting 80% emissions reductions in Oregon does not require decarbonized fuels if Oregon aggressively electrifies the demand side
  - With aggressive electrification and clean electricity, 80% target can be reached
- The 100x50 scenario (in line with the states around OR) requires all fuels to be decarbonized by 2050, increasing investment in electrolysis and biofuels
- 2030 CES achieved through already high mix of renewable generation in state and imported renewables from out-of-state

# Key Takeaways

## Resource Investment

- Oregon’s position between two much larger loads and interconnection in the West drive resource decisions
- Gas generation exported to other states is a component of Oregon generation through 2045 in 80x50 and through 2040 in the 100x50 scenarios
  – Gas remains a capacity resource in 2045
- Oregon supports regional energy solutions with offshore wind investment by 2050, exporting large amounts of clean electricity out of state
  – 20 GW built over 15 years requiring rapid industrial scaling
- Gas investments are replaced with renewables and other balancing solutions when investment in gas generation is limited to extensions of existing plants

# Key Takeaways

## Transmission

- Large expansion of Oregon transmission connections to other states by 2050 in 100x50 scenario
  - 6 GW to CA built from 2040 to 2050
  - 3.4 GW to ID built from 2030 to 2050
- Facilitates imports and exports of clean energy, taking advantage of geographic and resource diversity
  - Balancing of complementary resources shapes
  - Oregon exports of clean energy to California from offshore wind
  - Oregon imports of California and Southwest solar resource
  - East to west movement of energy from onshore wind resources in Wyoming and Montana
- West modeled as a single balancing area

# Key Takeaways

## Costs

- Approximately 0.2% GDP per year additional spending through 2035 on both 80x50 and 100x50 emissions trajectories (both target 45% below 1990 levels by 2035)
  - Lower than estimates in surrounding states to decarbonize their economies
- Net benefits in 2040 and beyond in 80x50 and 100x50
  - Emissions reductions are lower cost once the demand side is majority electrified and renewable resource prices have dropped according to their forecasts in 2040 to 2050
- Oregon is a large exporter of clean energy in 100x50. An In-State Only option is therefore not significantly different in cost to 100x50
  - Energy produced in both 100x50 and 100x50 In-State Only is directed locally in the latter with little impact on investments
- Low Transformation has a significant impact on costs (~0.4% of GDP more expensive between 2040 and 2050)
  - Greater energy demands and decarbonized fuels requirements increase total investments in the electricity system and fuels conversion technologies
  - Lower electrification means a larger electricity system when at 100x50

# Key Takeaways

## Grid Operations and Contracted Power

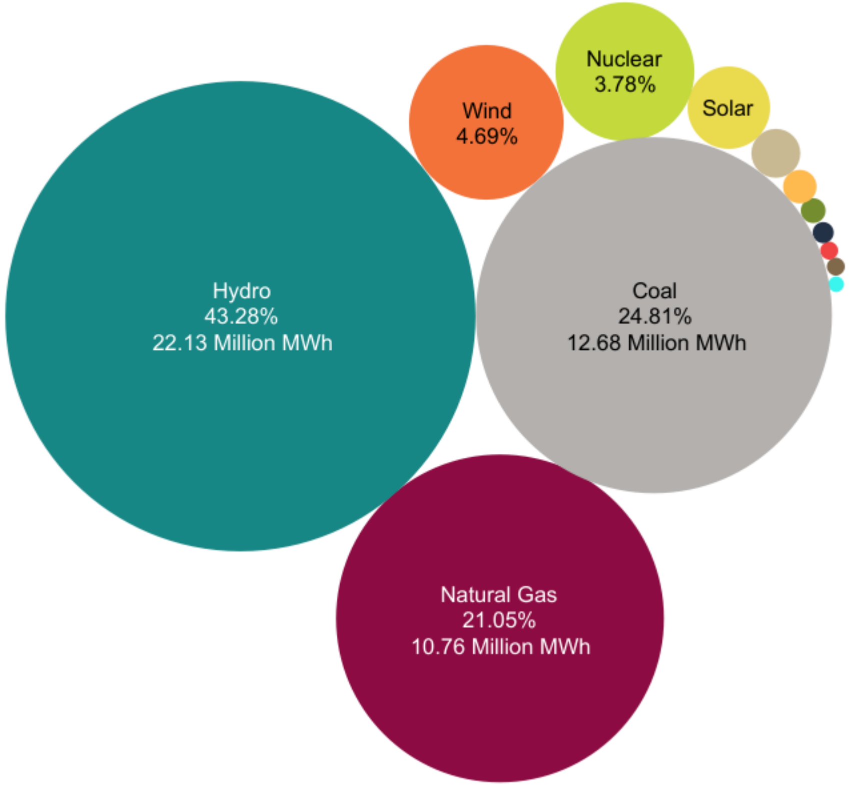
- Solution is based on physical system and does not account for contractual arrangements
  - Resources are dispatched as if the Western US is a single balancing area
  - Achieving the lowest cost regional decarbonization portfolio will require greater coordination of energy system planning and operations across the West
- Accounting mechanism important when determining cost of in-state resource policy
  - Existing resources within Oregon currently sold out of state (~3,000 MW) under contract are counted as in-state in the In-State Only scenario. If Oregon were required to replace these megawatts with additional in-state generation, costs of an In-State Only solution would be driven higher
- Assumptions include removal of coal from delivery to Oregon loads by 2025
  - Emissions reductions from switching away from coal are the primary means of meeting near-term Oregon emissions targets

# 2030 Target: Emissions Reductions in Oregon from removing Coal

Coal emissions constitute large amounts of emissions in OR that disappear under modeled CES

- 12.7 TWh of generation from coal in 2018
  - Equivalent to 1450 MWa coal generation
- Coal in Oregon
  - Boardman: 527 MW, retired 2020
- Coal ownership out of state
  - Colstrip 3+4: PGE (20%), PacifiCorp (10%)
  - PacifiCorp fleet (Pacific Power)
- Zero coal electricity sales permitted by 2025 in decarbonization cases; 2030 in Reference based on modeled CES

Oregon Electricity Use Resource Mix in 2018




https://www.oregon.gov/energy/energy-oregon/pages/electricity-mix-in-oregon.aspx#:~:text=%E2%80%8B%E2%80%8B%E2%80%8B%E2%80%8BIn,to%20wind%20and%20nuclear%20energy.&text=Most%20of%20the%20mix%20comes,wind%2C%20biomass%2C%20and%20solar.



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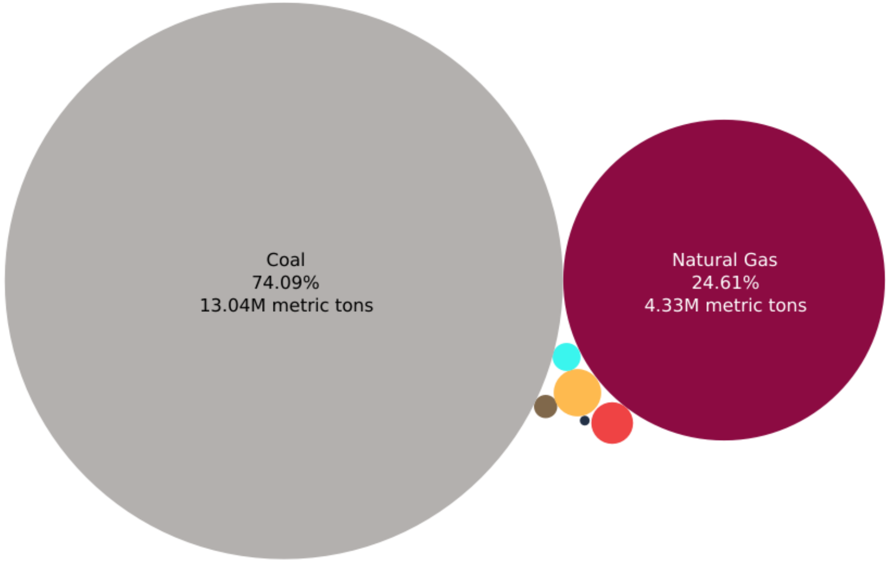
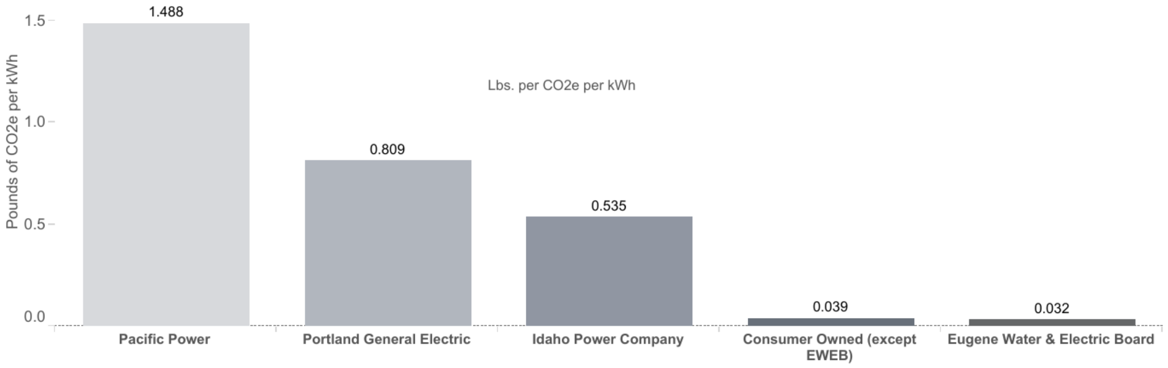
# Majority of Emissions from Electricity from Coal

- 16.6 MMT from coal emissions in 1990
- 13 MMT from coal emissions in 2018
- 18.8 MMT from electricity in 2019
- Removing coal gets Oregon all the way down to emissions target for 2030
  - *2030 economy-wide target based on 1990 levels is different from what is currently being discussed in Oregon right now*

Oregon GHG for Electricity Generation in 2018




https://www.oregon.gov/energy/energy-oregon/pages/electricity-mix-in-oregon.aspx#:~:text=%E2%80%8B%E2%80%8B%E2%80%8B%E2%80%8BIn,to%20wind%20and%20nuclear%20energy.&text=Most%20of%20the%20mix%20comes,wind%2C%20biomass%2C%20and%20solar.

# Key Actions in the 2020s

- **Electrification** of transport and buildings leads to lower cost decarbonization when going to 100x50
  - Early action required to achieve stock rollover of demand side technologies
  - Policy development: How best to promote the shift to electrified end uses? How to minimize the adverse impacts of doing so?
- **Retirement of coal** is Oregon's most impactful near-term path to achieving significant emissions reductions
  - Early action reduces the need for other emissions reduction solutions in the near term, allowing Oregon to procure renewable energy at lower prices in the future
  - Policy development: What are the steps needed to eliminate coal from the generation portfolio?
- **Regional operations** allowing Oregon to take advantage of out-of-state clean energy resources, export to other states, and planning for reliability are key to efficient decarbonization across the West
  - Early action needed to identify how regional coordination can facilitate increasing clean energy transmission and construction of new transmission lines
  - Policy development: What are the next steps to promote greater regional coordination?

# Key Actions in the 2030s

- **Renewable energy** investments beginning with onshore wind and solar, followed by large and rapid investment in offshore wind if forecasted prices remain as they are today
  - Ramp up offshore wind industry for rapid expansion between 2035 and 2050
- **100% electrification sales** by 2035 across light duty transport and building appliances
  - Early electrification key to avoiding large decarbonization costs in the future
- **Transmission expansion** if identified as feasible in planning during the previous decade
- **Greater regional coordination** to facilitate clean energy transfers across the West/US

# Key Actions in the 2040s

- **Electrolysis** ramping up to produce synthetic fuels and provide balancing for the electricity grid
  - Clean fuels economy develops earlier in other states that cannot reach emissions targets without it
  - Oregon utilizes clean fuels for final push to 100x50 after significant electrification, requiring lower volumes of clean fuel
- **Electrified end uses** reach close to 100% penetration in many sectors of the economy
  - What additional measures can be taken to electrify remaining primary fuel use by the 2040s?
- **Offshore wind** development ramps up significantly, reaching 20 GW by the end of the decade
- **Carbon neutrality achieved**

# THANK YOU

2443 Fillmore Street, No. 380-5034
San Francisco, CA, 94115

(415) 580-1804

info@evolved.energy

www.evolved.energy

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