Northwest Decarbonization Studies Insights: Opportunities for Montana

EVOLVED ENERGY RESEARCH

MARA

November 30, 2021

Agenda

- Introductions
  - Evolved Energy Research
- Key findings from decarbonization studies
  - Washington State Energy Strategy (2020)
  - Oregon Clean Energy Pathways Study (2021)
  - Montana findings from Northwest Deep Decarbonization Pathways Study (NWDDP) (2019)
- What are the opportunities for Montana in a decarbonizing West?

Introduction to Evolved Energy Research

Evolved addresses key policy and strategy questions raised by a transformation of our energy system to meet carbon emission goals

- What are the costs and challenges of meeting emissions policy targets?
- What does a realistic infrastructure investment plan look like?
- Where are the business opportunities and what impact will the energy transition have on people's lives?
- How will different pieces of the energy system interact in a decarbonized future?

Recent Clients

Includes Washington, Oregon, the Northwest, most Western states and several Western utilities

NGOs

NRDC, SDSN, GridLab, Sierra Club, CETI, OCT, UCS, EDF, CATF, BPC, Third Way, and others

State Energy Offices

Washington, Massachusetts, and New Jersey

Utilities

DTE, PGE, Hydro Quebec, and others

Others

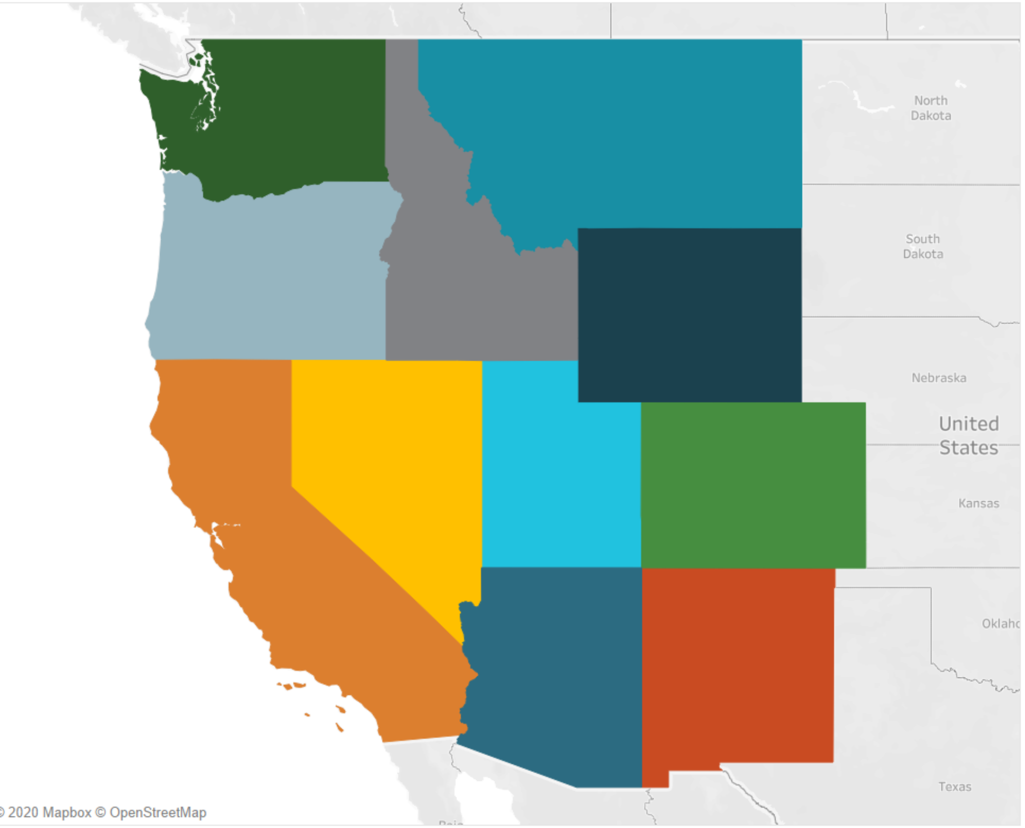
Princeton University, Breakthrough Energy, Inter-American Development Bank, DOE, NREL, and AGU Advances

Decarbonizing the Northwest in a West-wide Context

- Interconnected system in which Montana could play a key role
- Takeaways from other decarbonization studies indicate the opportunities for Montana in a decarbonizing West
  - Increased demand for clean energy resources across Western states through emissions and clean electricity targets
  - Increased load growth expected from electrification
- Key advantages - Low cost/high-quality renewable resources
  - High-capacity factor wind resources
  - Complementary with Southwest solar resources

Modeling Characteristics for Evaluating Clean Energy Pathways

Wholistic approach, integrated across geographies and economic sectors



- **Explores** pathways to achieve electricity and emissions targets in transitioning all economic sectors
- **Determines optimal resource investment**, constrained by scenarios, exploring state goals or uncertainties
- **Decarbonizing the energy supply**—electricity, pipeline gas, liquid fuels
- **Conservative** assumptions about existing technologies and cost projections from public sources
- Integrates electricity & fuels systems beyond state borders to **capture regional opportunities & challenges**

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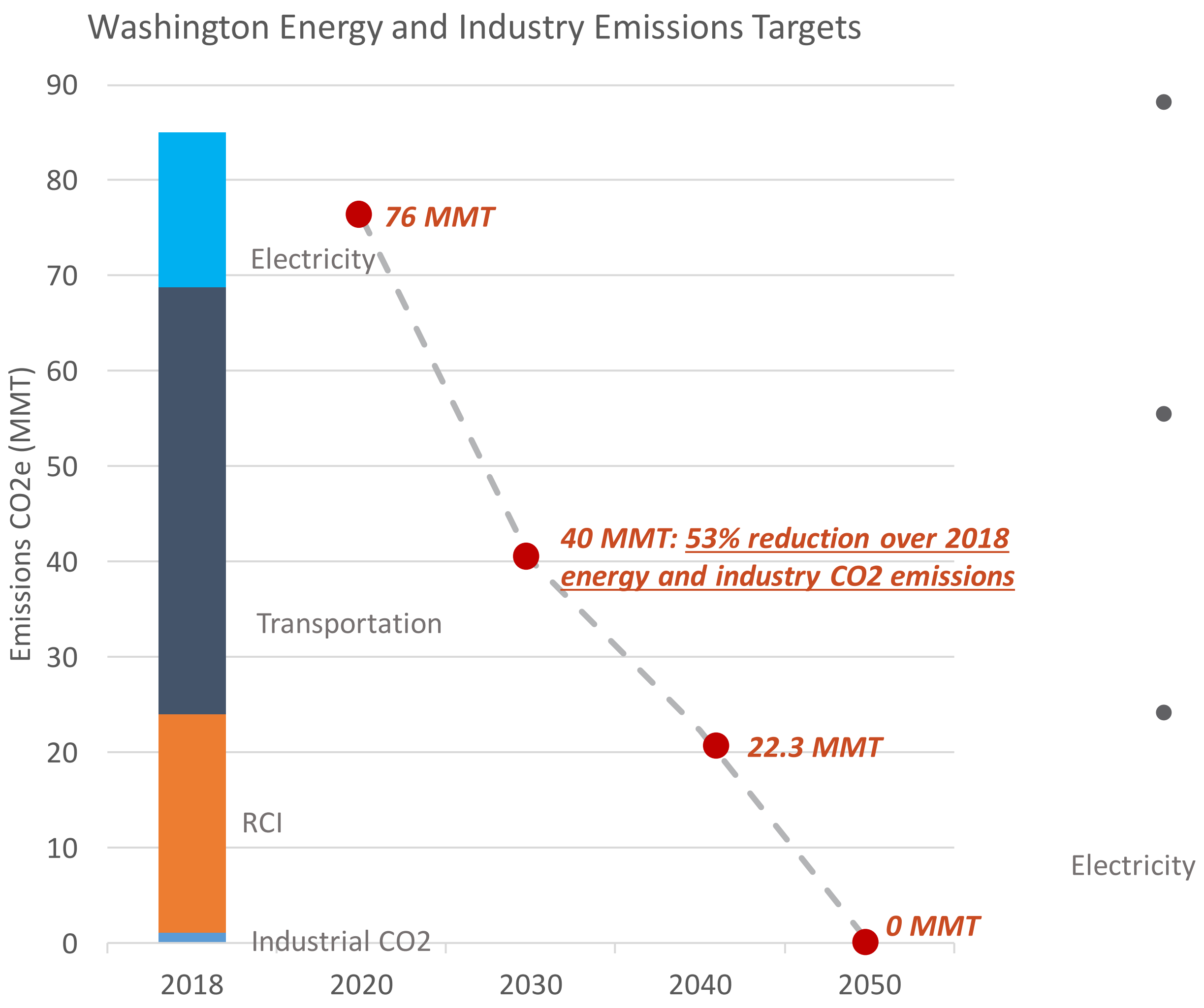
Summary: Washington State Energy Strategy

Washington becomes a net importer of energy from high quality out-of-state resources such as Montana wind. Aggressive 2030 target fosters early development of clean fuels economy.

2030: The Energy Emissions Challenge

The DDP modeling analyzes how the CO_2 energy and industry emissions targets can be met

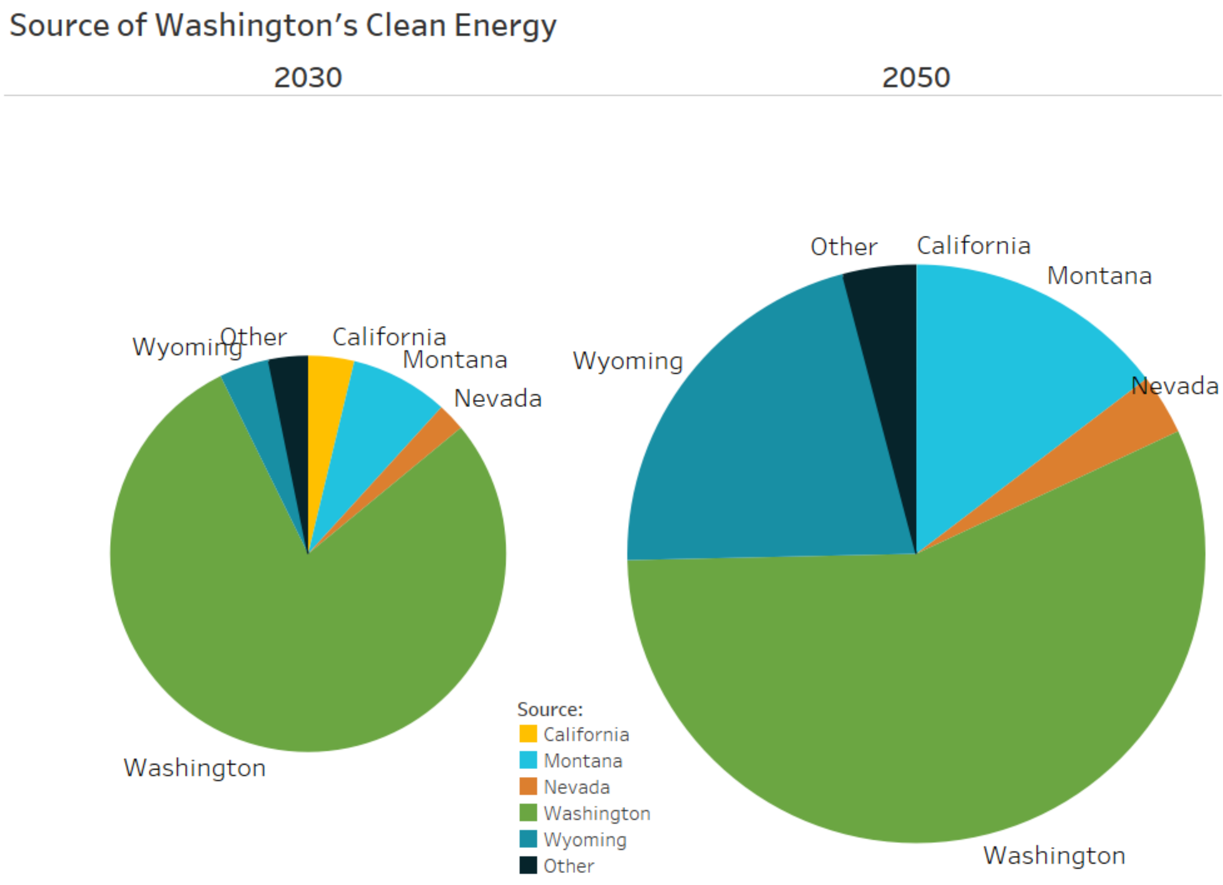


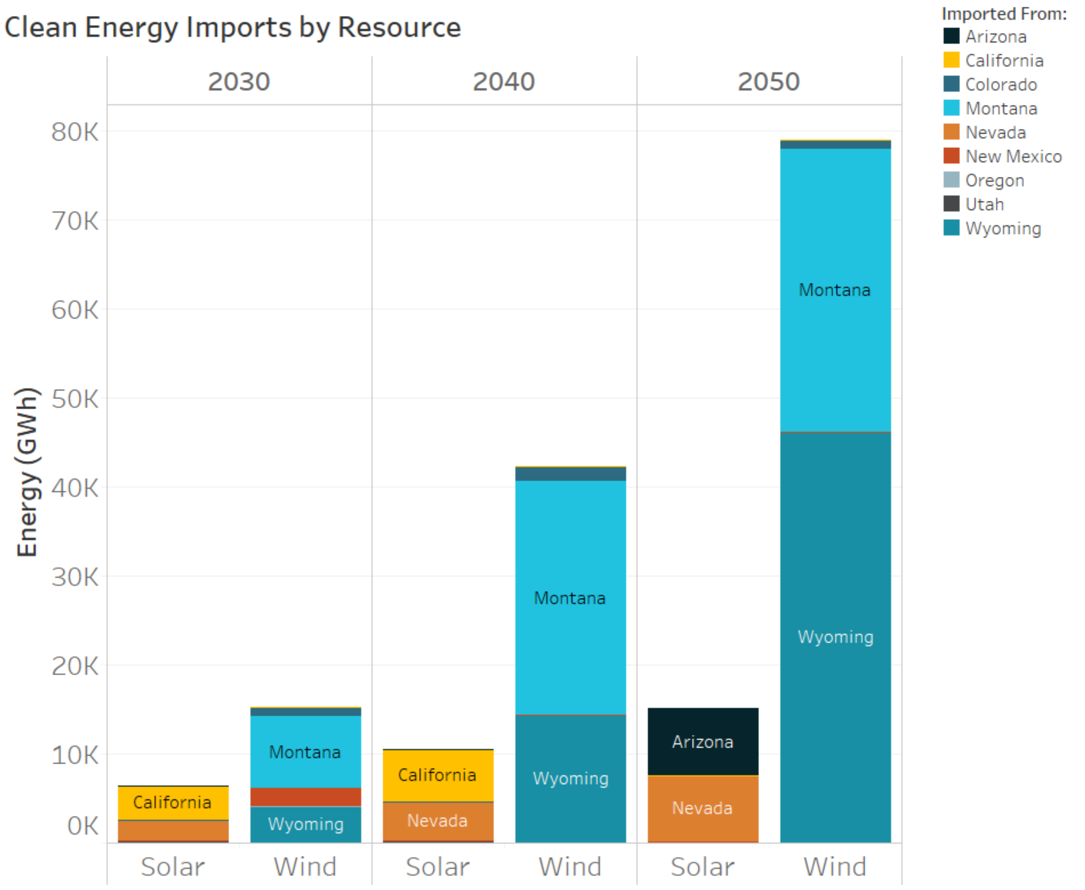
- 2030 emissions target for energy and industry less than half of 2018 emissions
  - 40 MMT assumes linear decreases in non-CO_2 emissions and linear increases in incremental land sink through to 2050
- Washington's electricity sector is already very clean: Early emissions reductions are required from actions in other sectors to meet the 2030 target
- **The 2030 challenge: How to cut emissions in half in 10 years?**

Where do Imports Come from?

Clean electricity imports from Electrification Case

High quality wind resources from Wyoming and Montana account for 36% of WA clean electricity in 2050





Regional Capacity in 2050

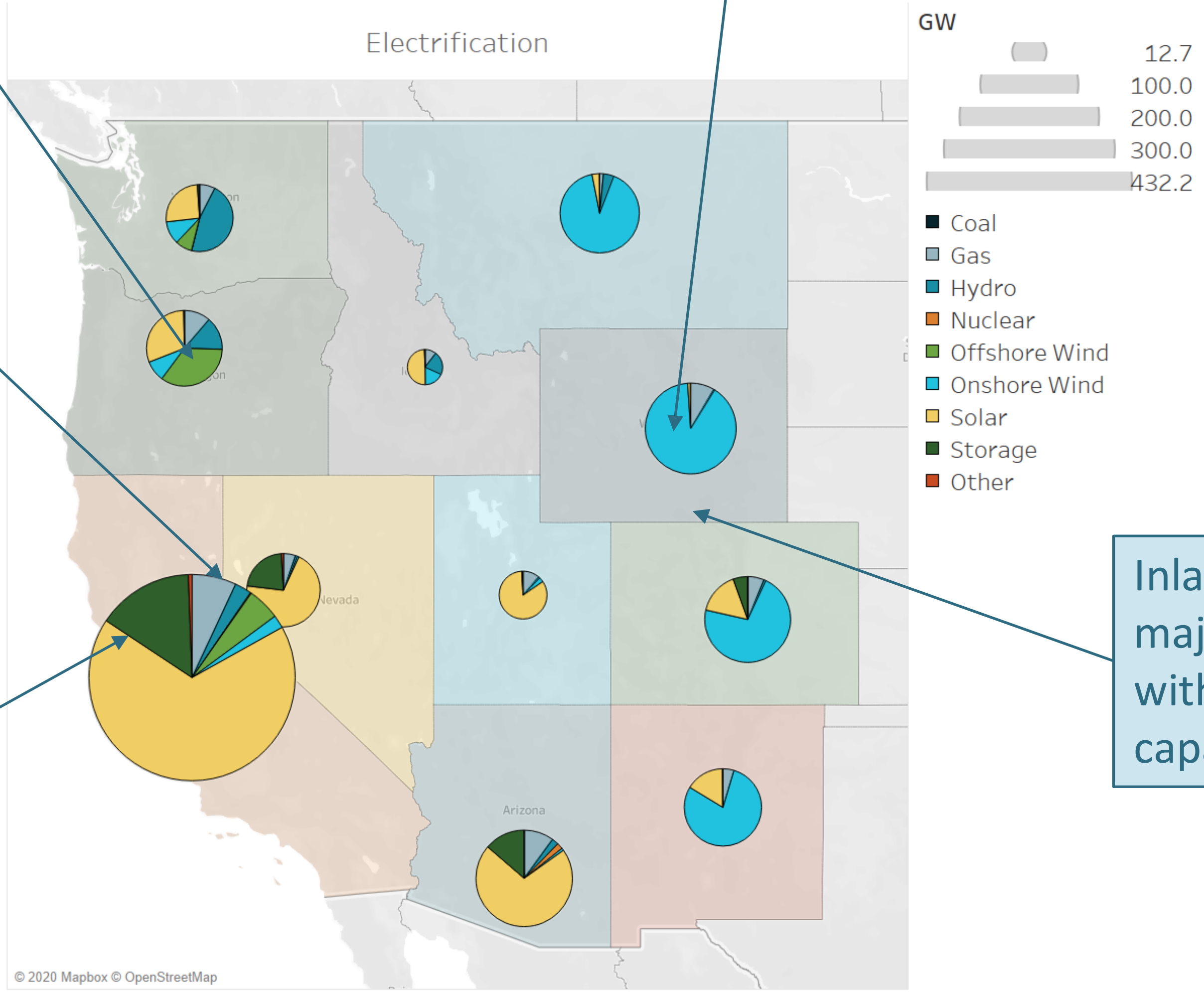
Electrification Case

Offshore wind built in Northwest and California to meet 2050 clean energy needs

Gas capacity provides reliability but very little energy in 2050

Large quantity of storage built in solar states for diurnal balancing

Large wind resource complements Southwestern solar resource

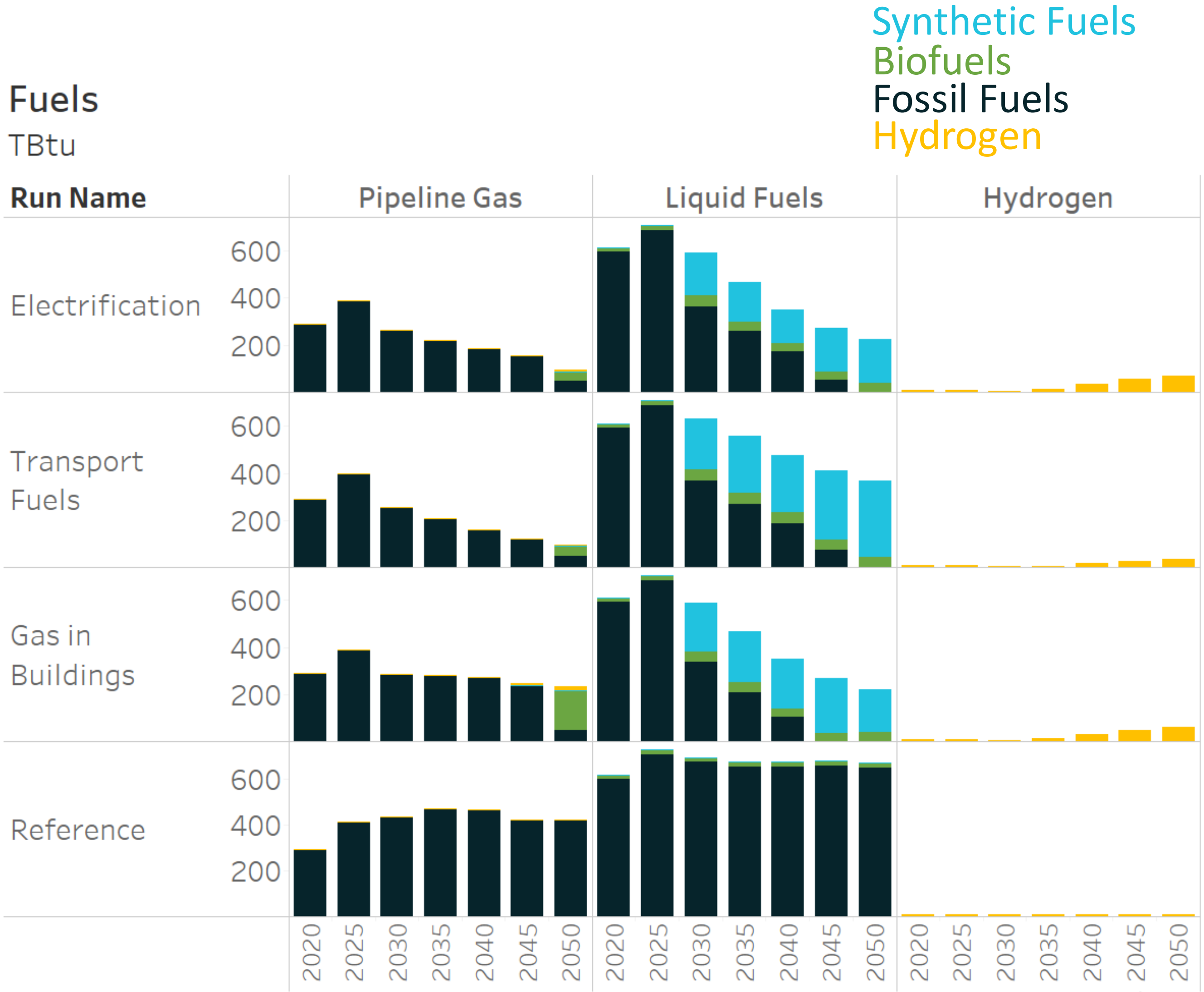


Inland states become major exporters of wind with majority wind capacity systems by 2050

Clean Fuels are Important to Reach Decarbonization Targets

Washington starts from a clean electricity sector and needs emissions reductions from other sectors

- All liquid fuels are fully decarbonized by 2050
- Decreasing fuel consumption over time with electrification and efficiency
- Liquid fuels (gasoline, diesel, jet fuel, others) significantly decarbonized by 2030 with synthetic and biofuels
  - Significant growth in clean fuels industries with few current commercial operations
  - Challenge for Washington to reach 2030 targets
- Hydrogen demand driven by long-haul trucking fleet
- Majority emissions in 2050 from natural gas in primary end uses



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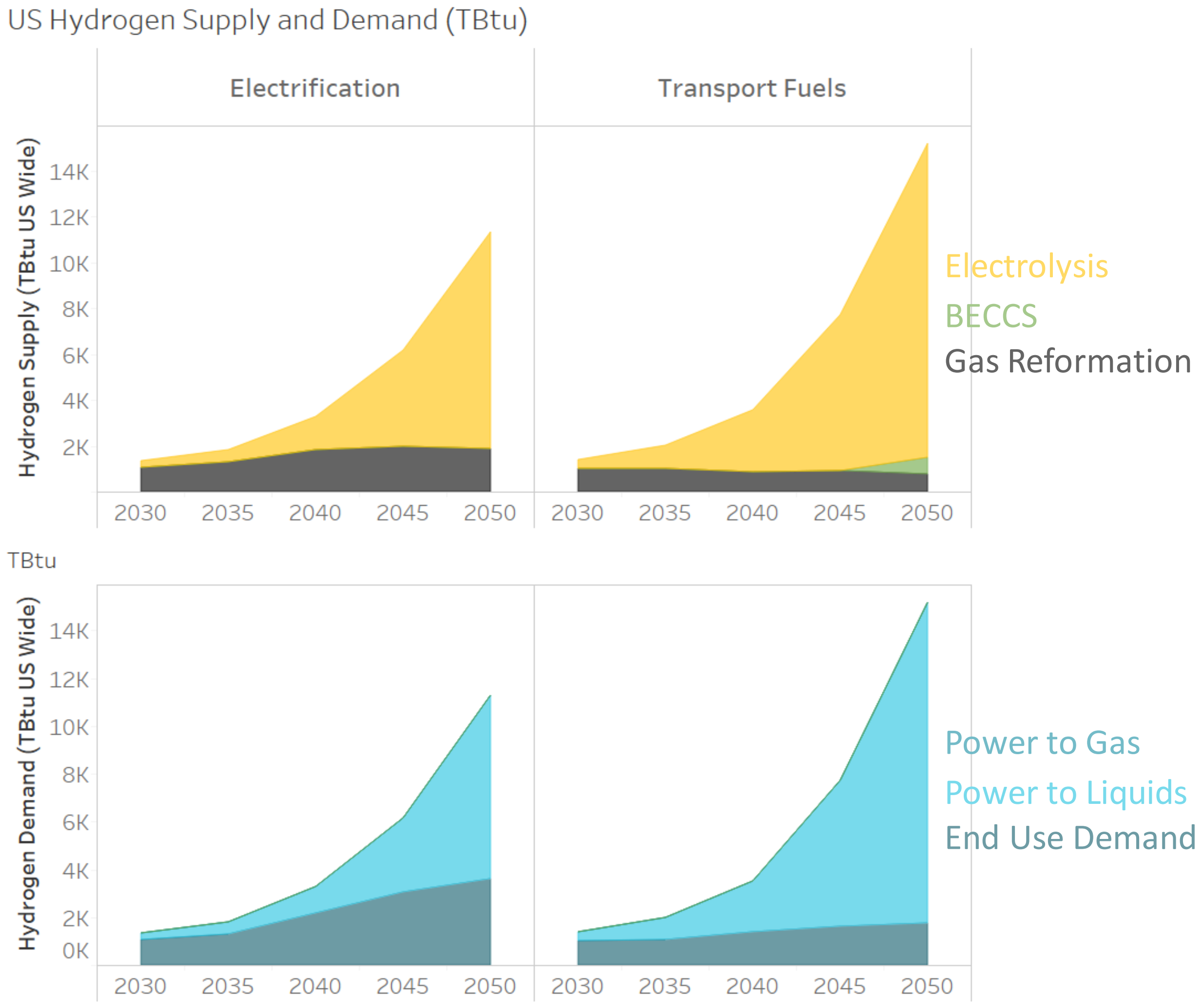
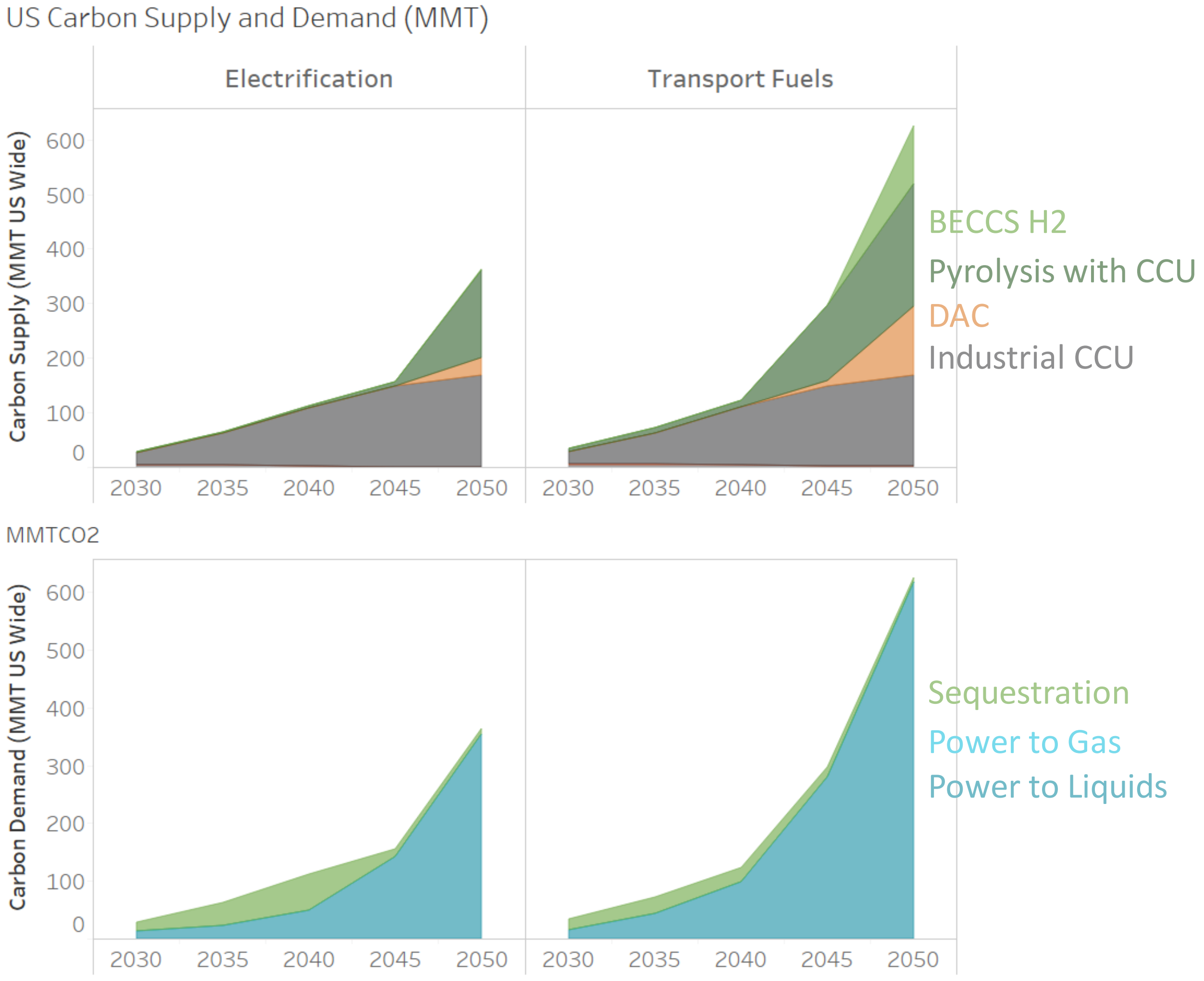
National Fuels Industry in 2050: Hydrogen and Carbon

Building blocks of synthetic fuels, drives demand for biomass and renewable energy





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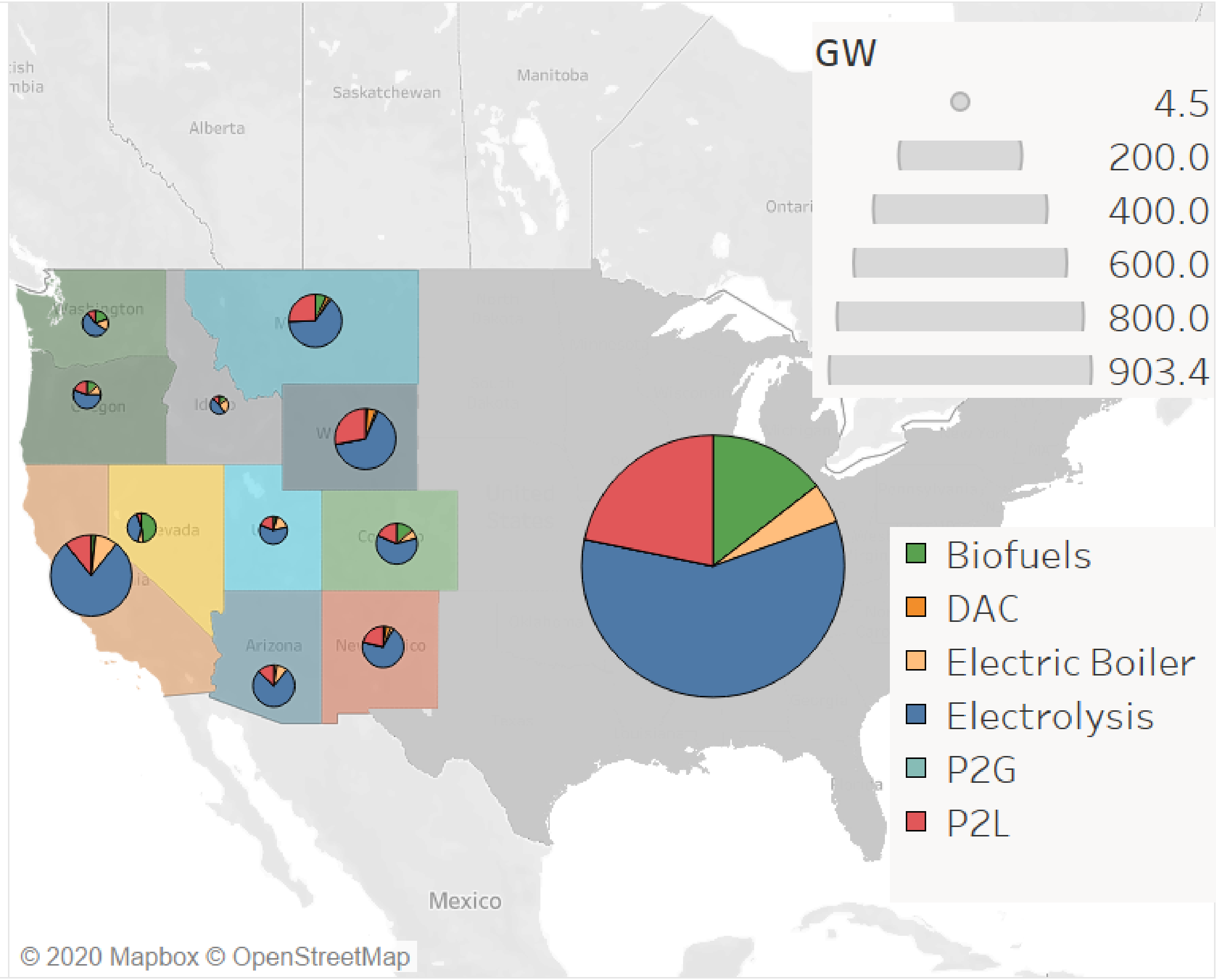
Fuels Production Capacity by 2050

National production capacity to serve US needs

- Large total conversion capacity investment needed across the US to produce clean fuels
  - Includes demand from other states
- WA demand met with investment in fuels conversion infrastructure, biomass, and clean electricity
- Greater capacity investment needed to meet bio and synthetic fuels demand in Transport Fuels Case
  - Increased WA demand met with investment in fuels production infrastructure



Washington State Decarbonization Modeling Key Findings

- Challenges of decarbonization are pace of action in the near-term (2030) and scale in the long-term (2050)
- Washington's electricity supply emitted 16.2 MMT CO_2e in 2018 of the 44.8 MMT CO_2e required to reach the 2030 goal:
  - Decarbonizing the 2018 electricity supply cannot play a large role in accomplishing the 2030 goal
- Even with GHG-neutral electricity, 2030 emissions target is challenging
  - Focus must be on demand side and fuels: Energy efficiency, electrification, decarbonized fuels
  - Stock rollover of technologies with long lives raise the question of how much efficiency and electrification can be accomplished in 10 years
- **Washington requires regional energy solutions to accomplish the emissions targets**
  - **Significant imports of clean energy in the form of electricity and fuels are present in all scenarios**

Washington State Decarbonization Modeling Key Findings

Continued

- Synthetic fuels production plays a major role in decarbonizing Washington's economy as well as balancing the electricity grid
  - Balancing through electrolysis in the state and as part of the regional balancing solution
  - Early need for clean fuels to meet Washington targets, displacing transport and industrial fuels
- Washington state resource balancing provided by hydro, electrolysis, flexible loads, and imports as part of the integrated balancing capability of the rest of the West
- **Significant imports of clean energy from wind-rich states support Washington's electricity needs – 43% by 2050 in Electrification Case**
  - **Regional coordination is key to Washington and Western decarbonization**

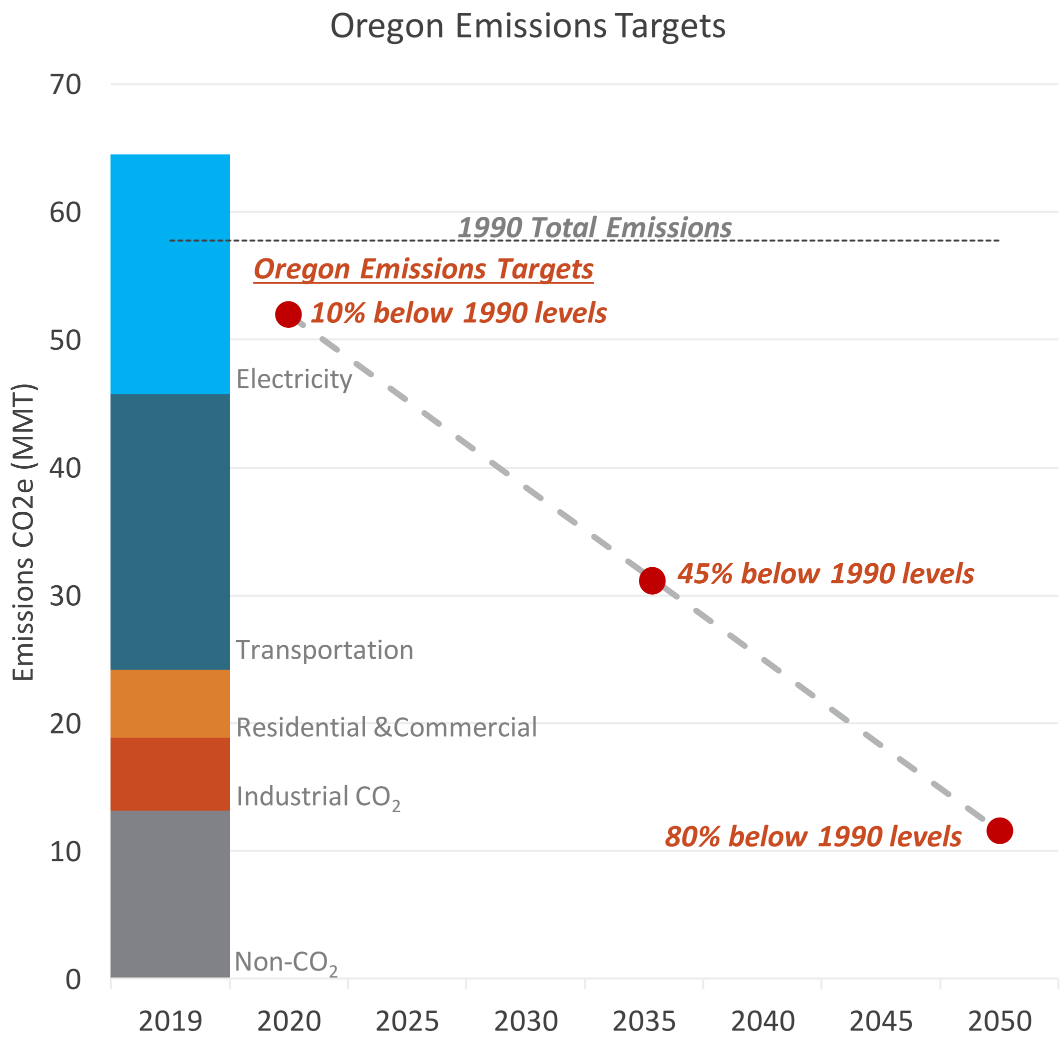
Summary: Oregon Clean Energy Pathways Study

Oregon removes coal from electricity portfolio and becomes a net exporter by developing offshore wind resources.

Goals of the Project

- Examined the technical and economic implications of accelerating decarbonization in Oregon 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?*

Oregon Emissions Targets



- Oregon established economy-wide emissions goals of 10% below 1990 levels in 2020 and 75% below 1990 levels in 2050
- Targets 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% below 1990 levels by 2050 for energy and industry**

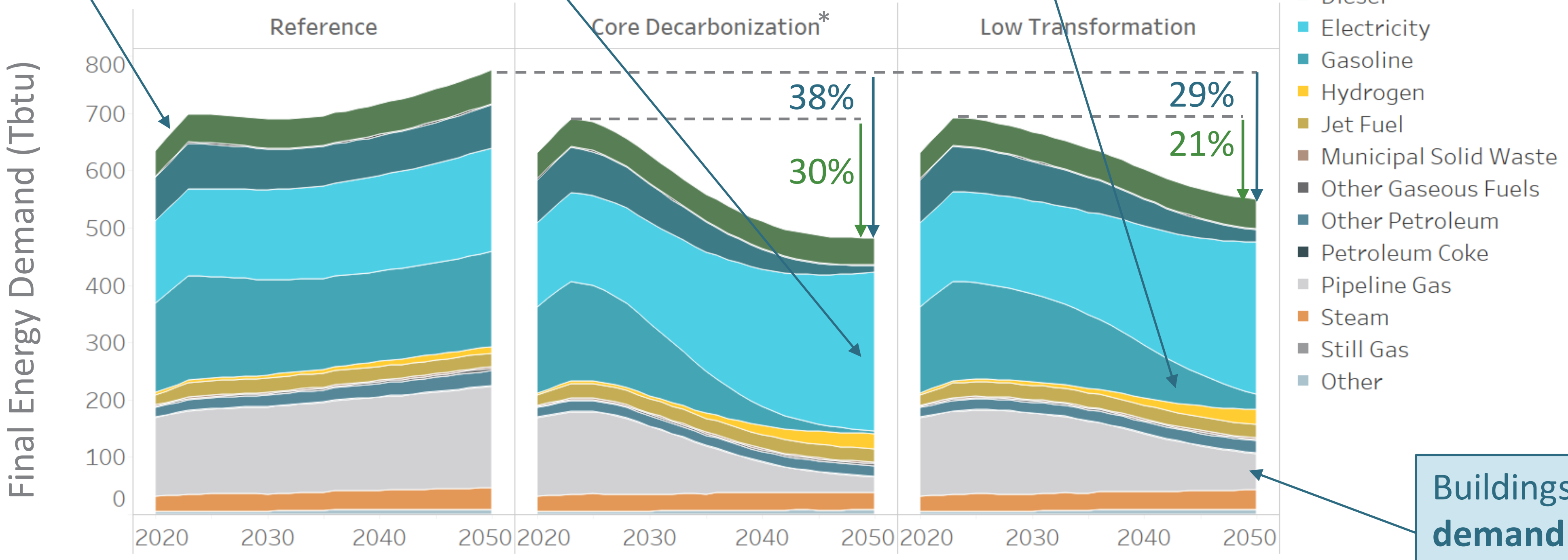
Final Energy Demand

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

Generation and Load

80x50: Gas exports remain in small quantities by 2050

20 GW offshore wind by 2050 supplying exports

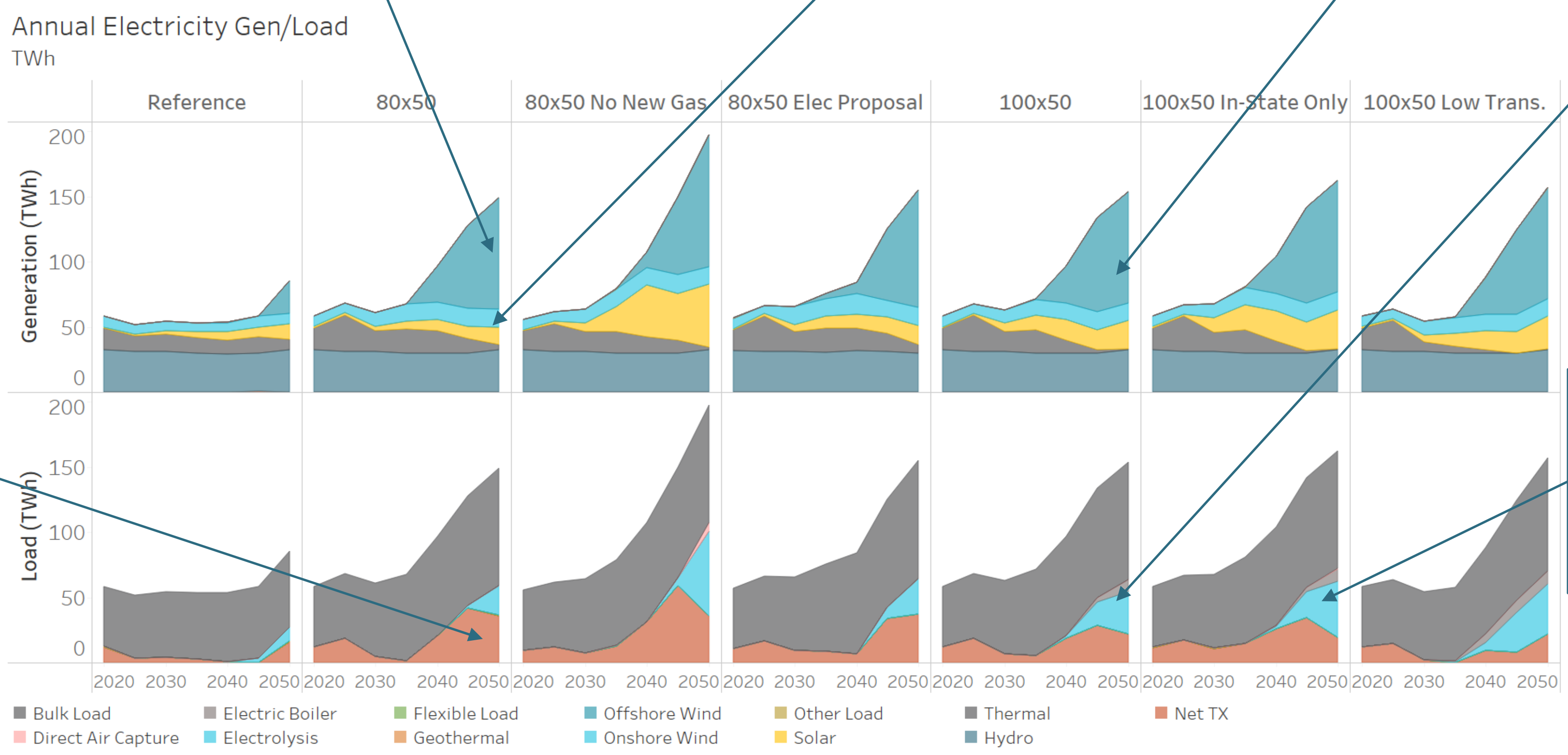
7 GW of solar including assumed 6 GW of rooftop

Net Zero: 20 GW of offshore wind, 10 GW of solar

Electrolysis provides balancing and clean fuels in 2050

Net exports of clean electricity driven by offshore wind investment

Increase in RE and balancing by 2050 in in-state only case



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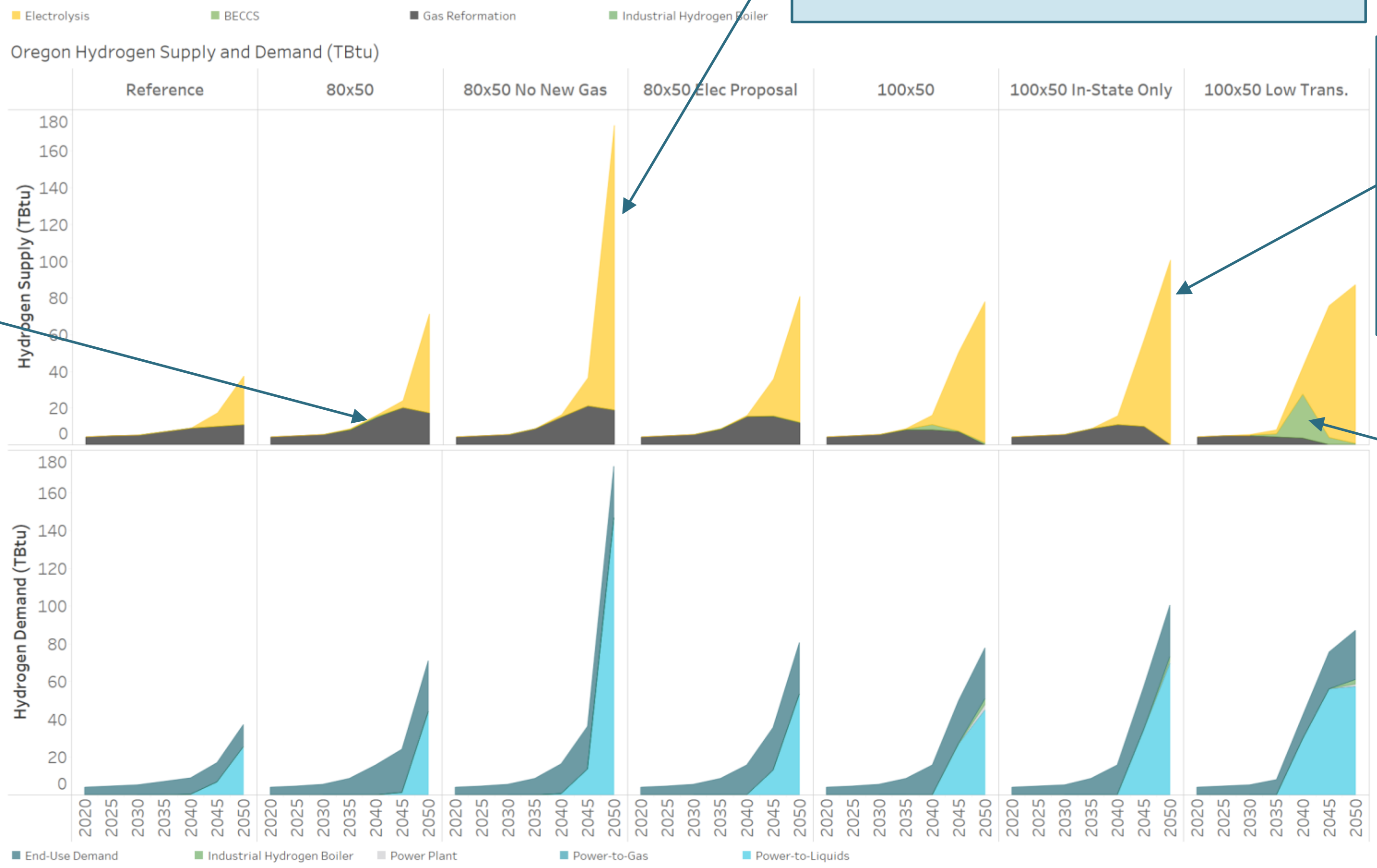
Hydrogen Supply and Demand

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



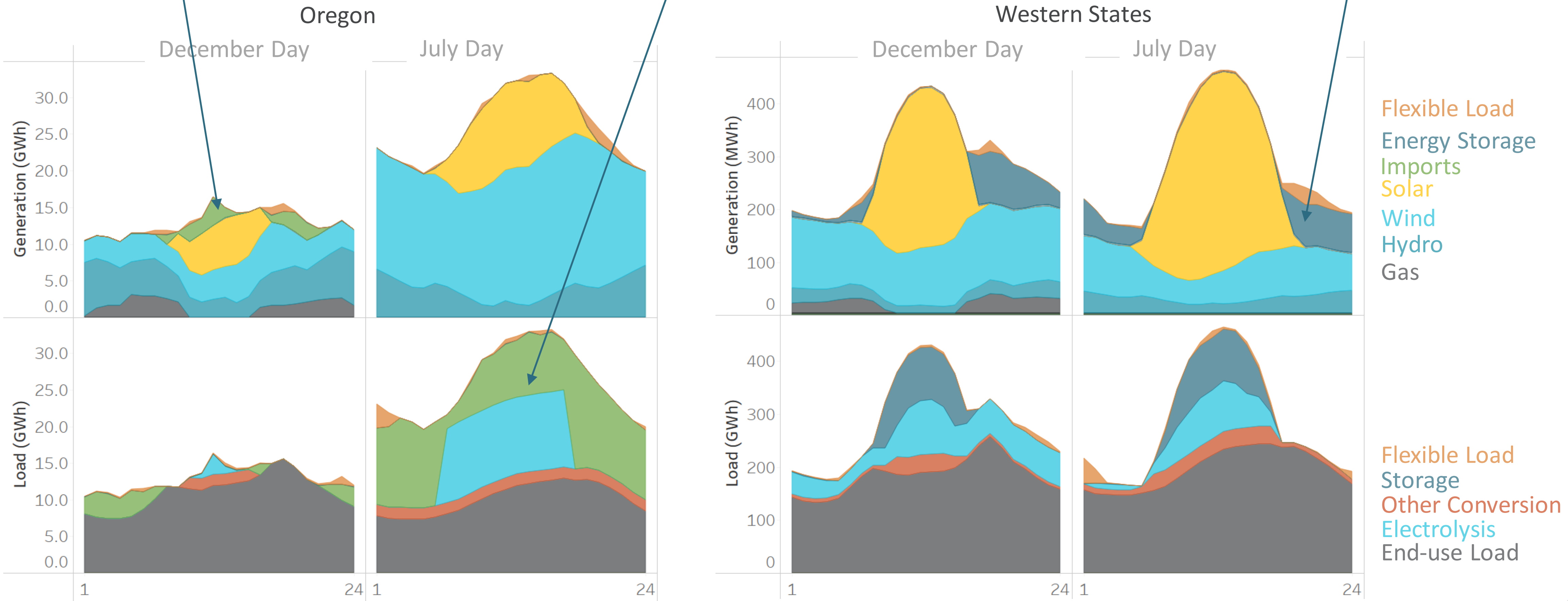
Balancing the System: High Energy and Low Energy Days in 2050

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

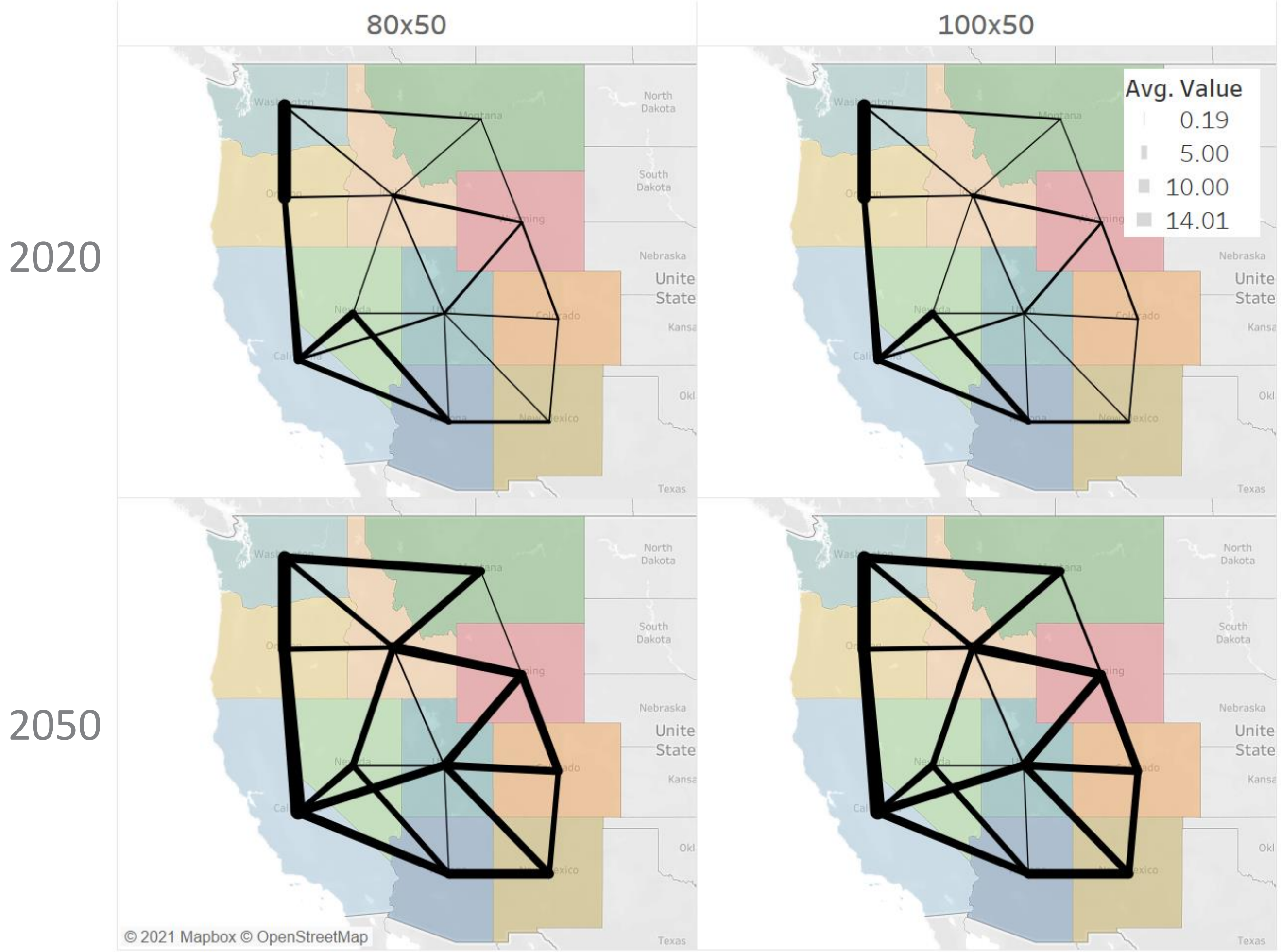
Significant storage build in the rest of the West helps balance diurnal solar shape



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



Oregon Decarbonization Modeling 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
- Oregon's position between two much larger loads and interconnection in the West drive resource decisions
- 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

Oregon Decarbonization Modeling 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**

Oregon Key Actions in the 2020s

- **Retiring 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
- **Electrification** of transport and buildings leads to lower decarbonization costs when achieving net zero emissions
  - Early action required to achieve stock rollover of demand side technologies
- **Regional operations** that allow Oregon to take advantage of out-of-state clean energy resources; exporting clean resources 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

Oregon Key Actions in the 2030s

- **Renewable energy** investments in state beginning with onshore wind and solar, followed by large and rapid investment in offshore wind, if forecast 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

Oregon Key Actions in the 2040s

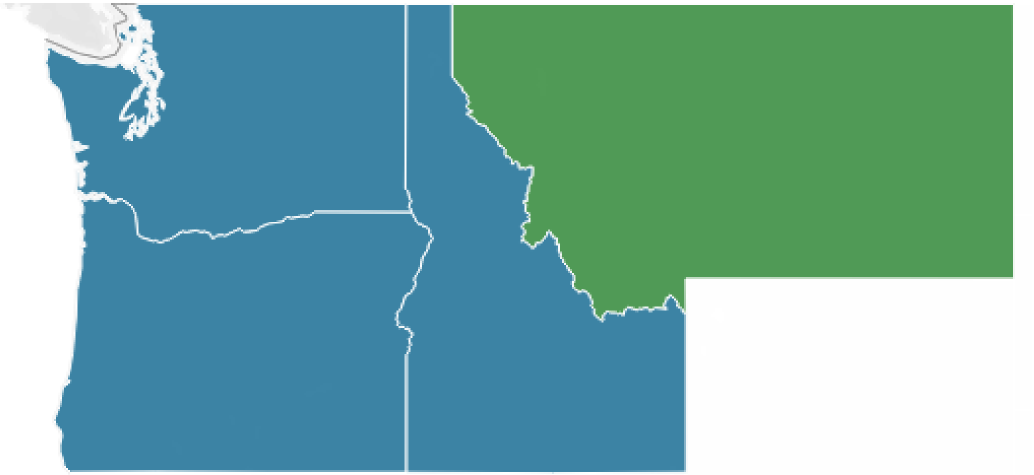
- **Electrolysis** ramps up to produce synthetic fuels and provide balancing for the electricity grid
  - Clean fuels economy develops earlier in other states that cannot reach emissions targets without it
  - Oregon uses clean fuels for final push to net zero emissions after significant electrification, 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**

Summary: Montana Findings from NWDDP

Electrify, decarbonize fuels, and become a net exporter of electricity to the West.

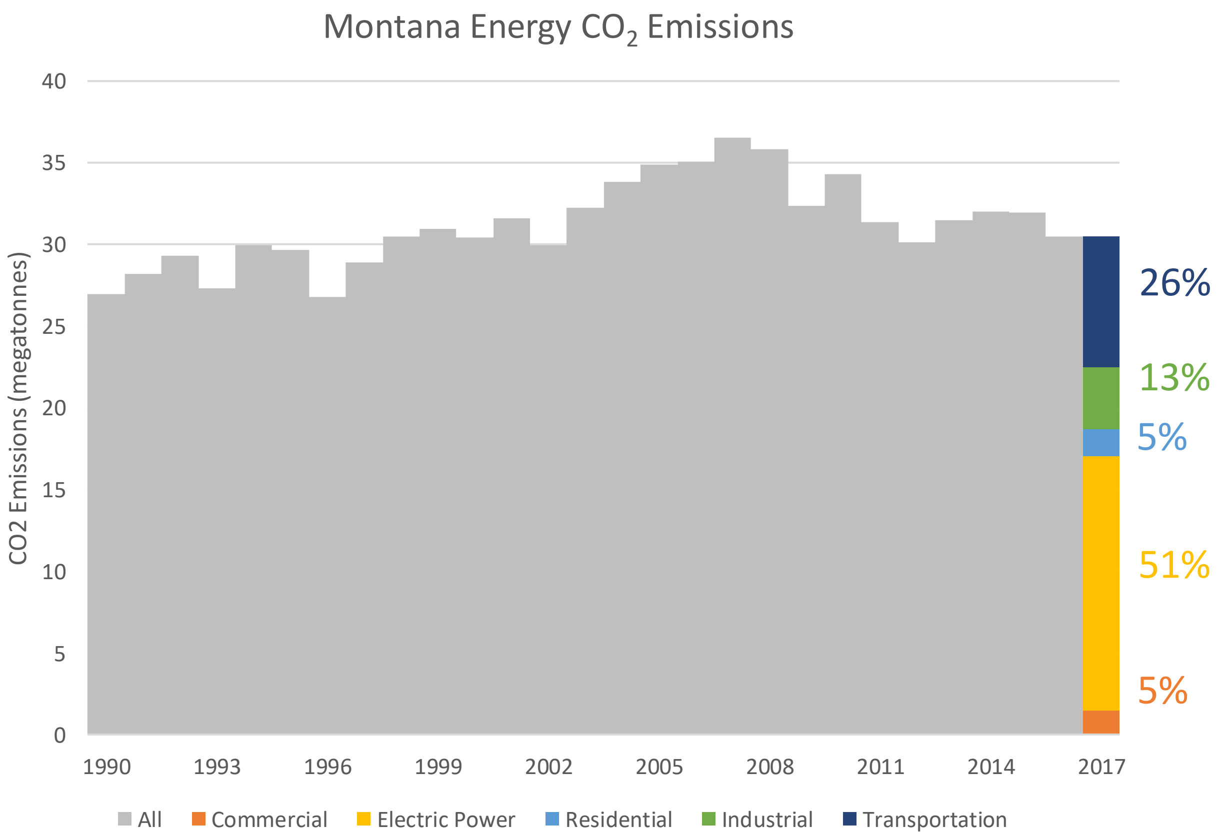
Analytical Context

- The Northwest Deep Decarbonization Pathways (NWDDP) analysis was conducted using state-level granularity to determine least-cost pathways
- The study released in June 2019 summarized results for the region, including Idaho, Montana, Oregon, and Washington
- This section presents results and insights specific to the state of Montana



Historical Montana Energy-Related CO_2 Emissions

- Half of the emissions from within Montana's borders come from electric power
  - Montana's 2007 emissions inventory shows that ~50% of those emissions were from electricity exported to other states in 2005
- The transportation sector accounts for a quarter of all energy-related CO_2 emissions, primarily due to liquid fossil fuel consumption:
  - Gasoline fuel in passenger transportation
  - Diesel fuel in freight transportation
  - Jet fuel in aviation

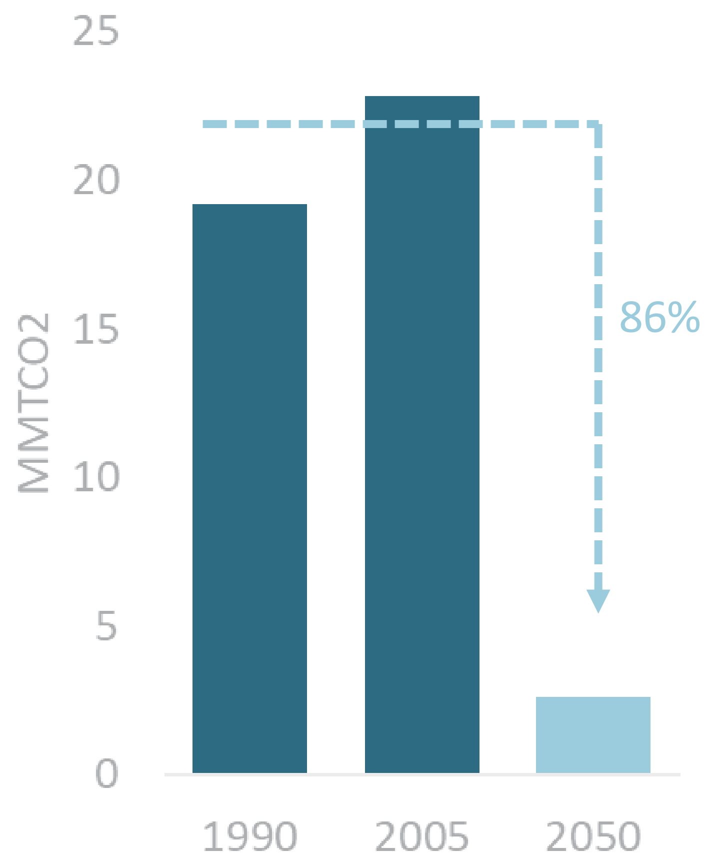


Sources: U.S. Energy Information Administration (EIA), State Energy Data System and EIA calculations made for this table. United States national-level total, EIA Monthly Energy Review, July 2019 Section 11.

NWDDP Deep Decarbonization Target

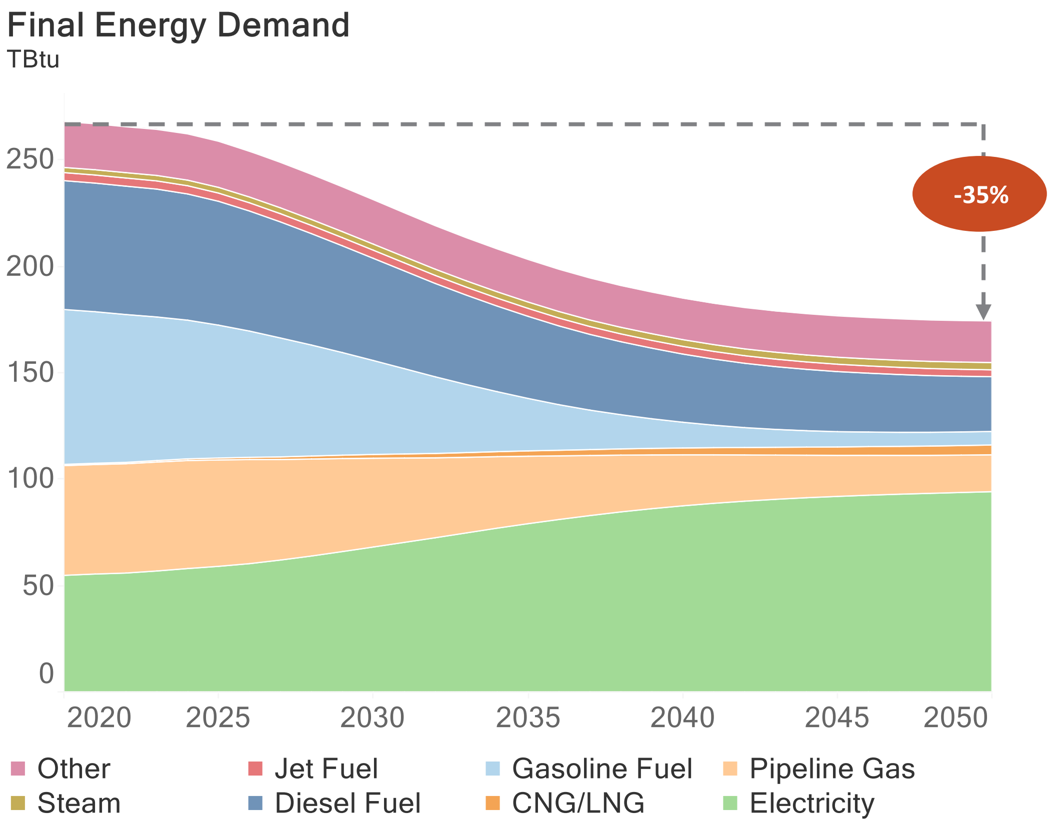
- **Target**: 86 percent reduction in energy-related CO_2 emissions below 1990 levels by 2050
- Energy target is consistent with an economy-wide GHG reduction target of 80 percent below 1990 levels by 2050
  – Allows for reductions below 80 percent for non-energy CO_2 and non-CO_2 GHG emissions, where mitigation feasibility is less understood

NWDDP Montana Energy Emissions Target



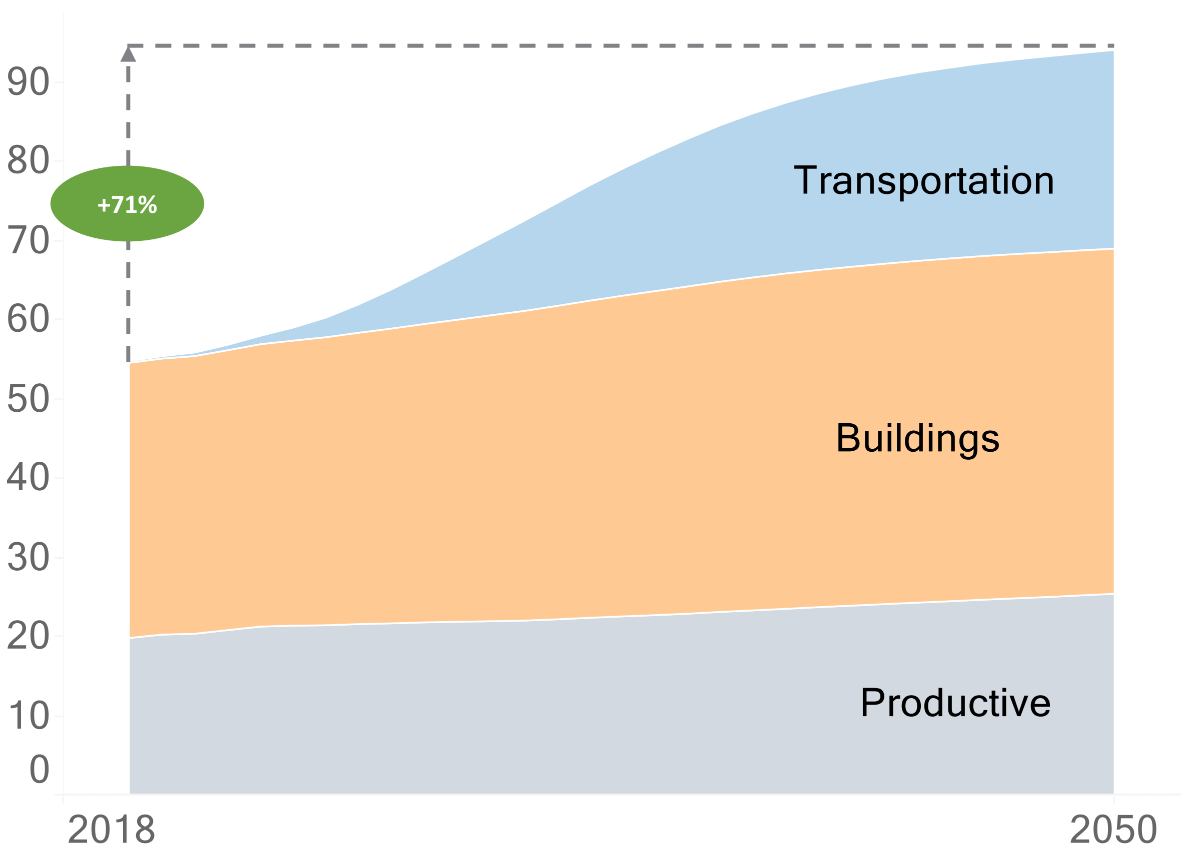
Montana Energy Demand: End-Use Consumption

- End-use consumption, or final energy demand, represents energy used in the delivery of services such as heating or transportation
  - Excludes energy consumed in converting to other forms of energy (e.g., pipeline gas consumed by power plants)
- Overall end-use demand in 2050 is one-third below today
  - Electricity consumption increases by more than 70% and comprises one-half of all end-use consumption by 2050
  - Gasoline and diesel decrease from one-half of demand today to one-fifth by 2050 as on-road vehicles transition to electricity



Montana Energy Demand: Retail Electricity Sales by End-Use

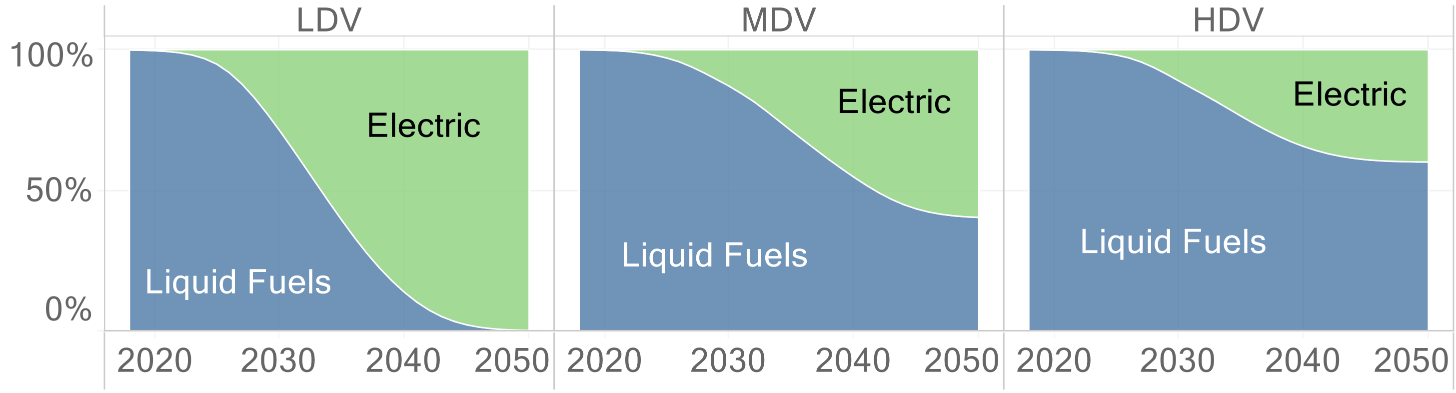
- Net increase in end-use electricity consumption is primarily related to electrifying passenger and freight transportation
- By 2050, all passenger vehicles on the road are electric, whereas about half of freight trucks are
  - Freight trucks that continue to use liquid fuels primarily consume renewable diesel in the 2050 timeframe



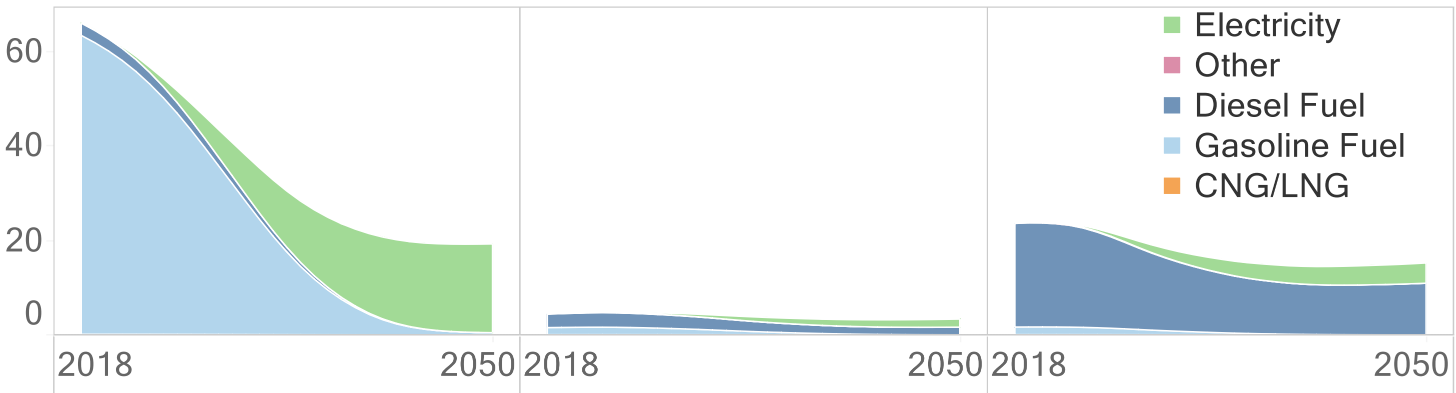
Montana Transportation Electrification

- Vehicles on the road rapidly transition from liquid fuels to electric
  - Aggressive adoption over the next three decades is necessary
- This results in an overall decrease in final energy demand due to the efficiency of an electric powertrain relative to an internal combustion engine

Vehicles on the Road
% of Total



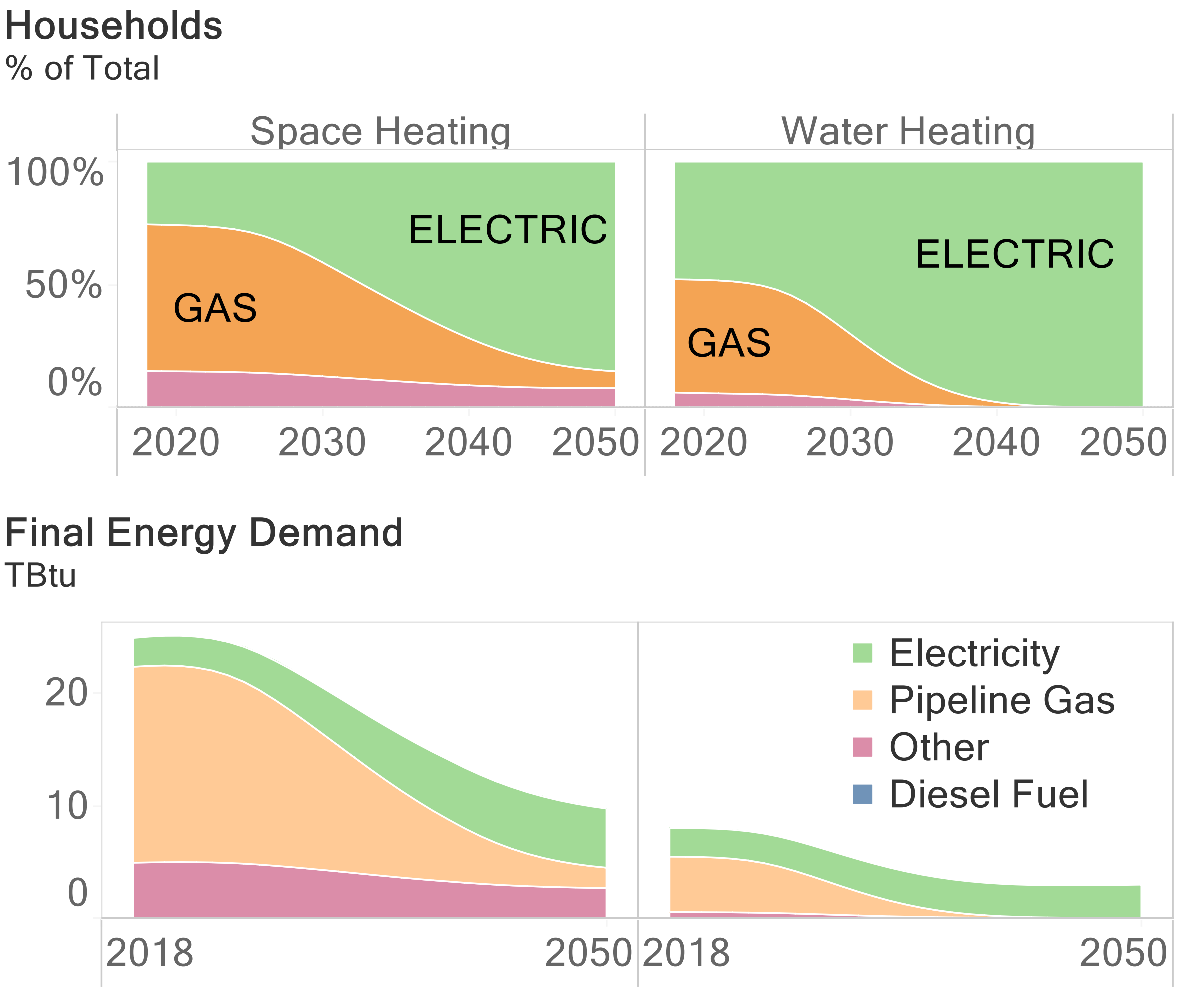
Final Energy Demand
TBtu



Montana Building Electrification

Example: Residential Buildings

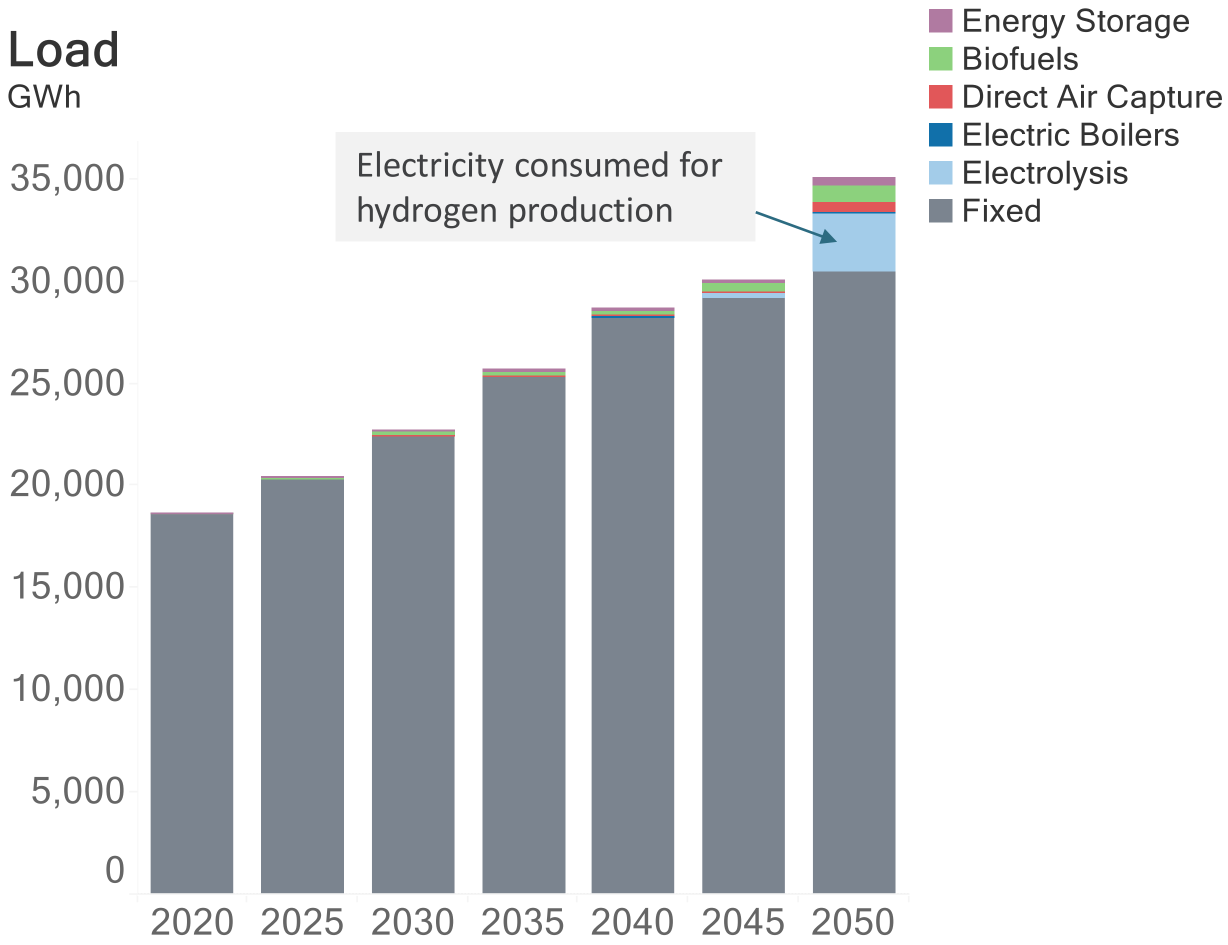
- Energy consumption from buildings decreases significantly over time despite the growth of households and floorspace
- Electrification of space and water heating translates into deep energy use reductions due to the efficiency of heat pump technology relative to the best in-class combustion equipment
- This same trend is observed in commercial building stocks, as well as other end uses such as cooling and water heating



Energy Demand: Transmission-Level Electric Load

Montana

- Transmission-level load increases by 90 percent between 2020 and 2050
- A large portion of the net increase is from higher “fixed” loads (e.g., end-use retail sales)
- However, another significant portion of load growth in the state is from electrolysis facilities, which produce hydrogen primarily for synthetic fuels

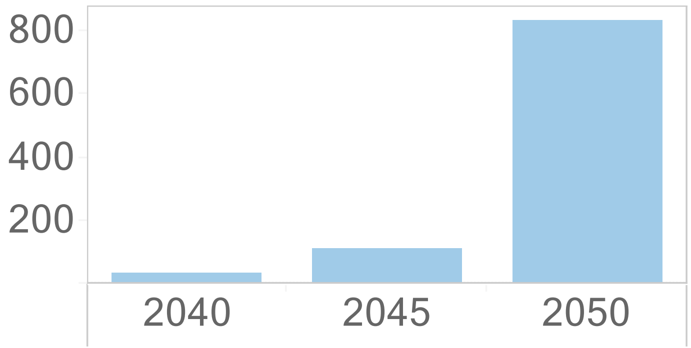


New Sources of Electric Load

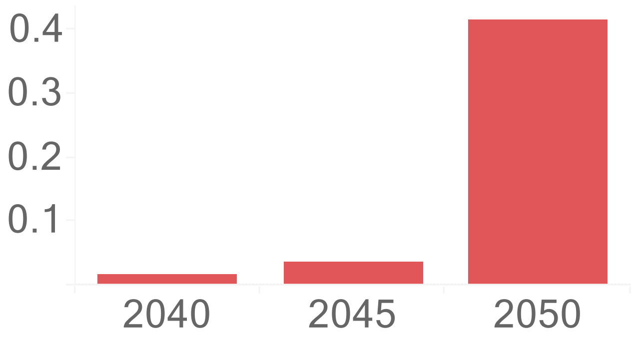
Montana

- Large, flexible sources of electric load help Montana manage electricity imbalances across the year
- Most of the new loads produce inputs for synthetic natural gas production, while electric boilers produce steam for commercial and industrial activity

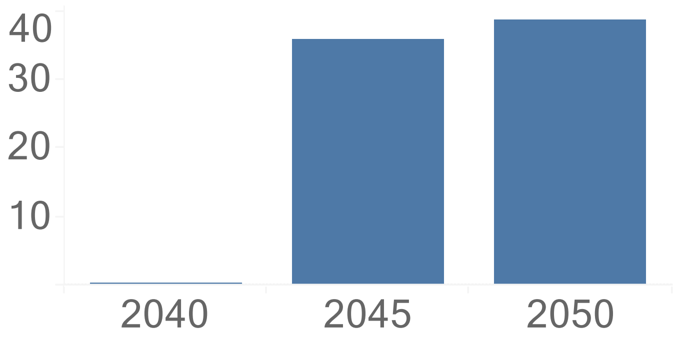
Electrolysis Capacity
MW



DAC Total Capture Capacity
MMT per year



Electric Boiler Capacity
MW



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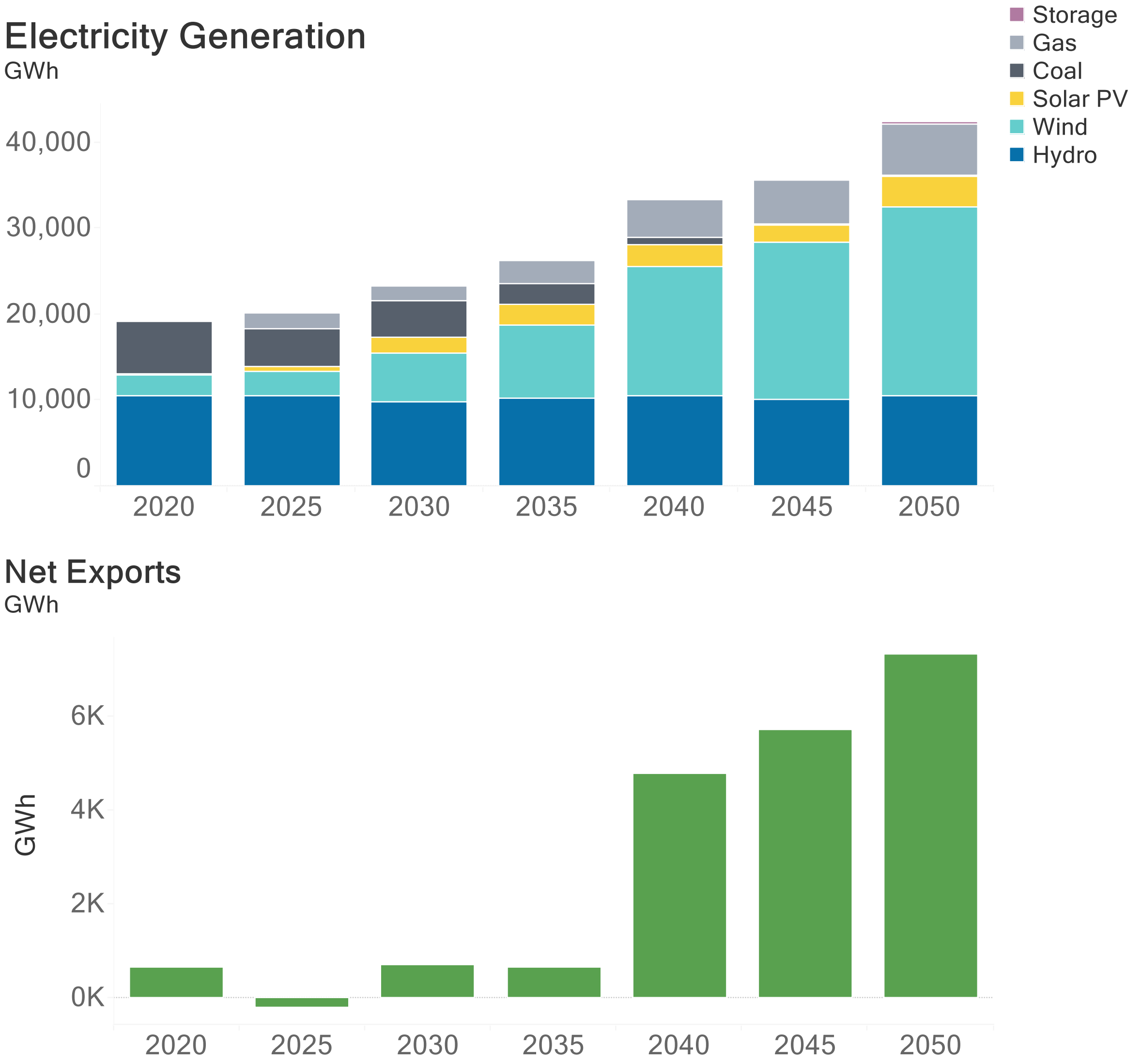
Exports Increase with Development of Montana Wind Sector

Montana Net Exports in the Central Case

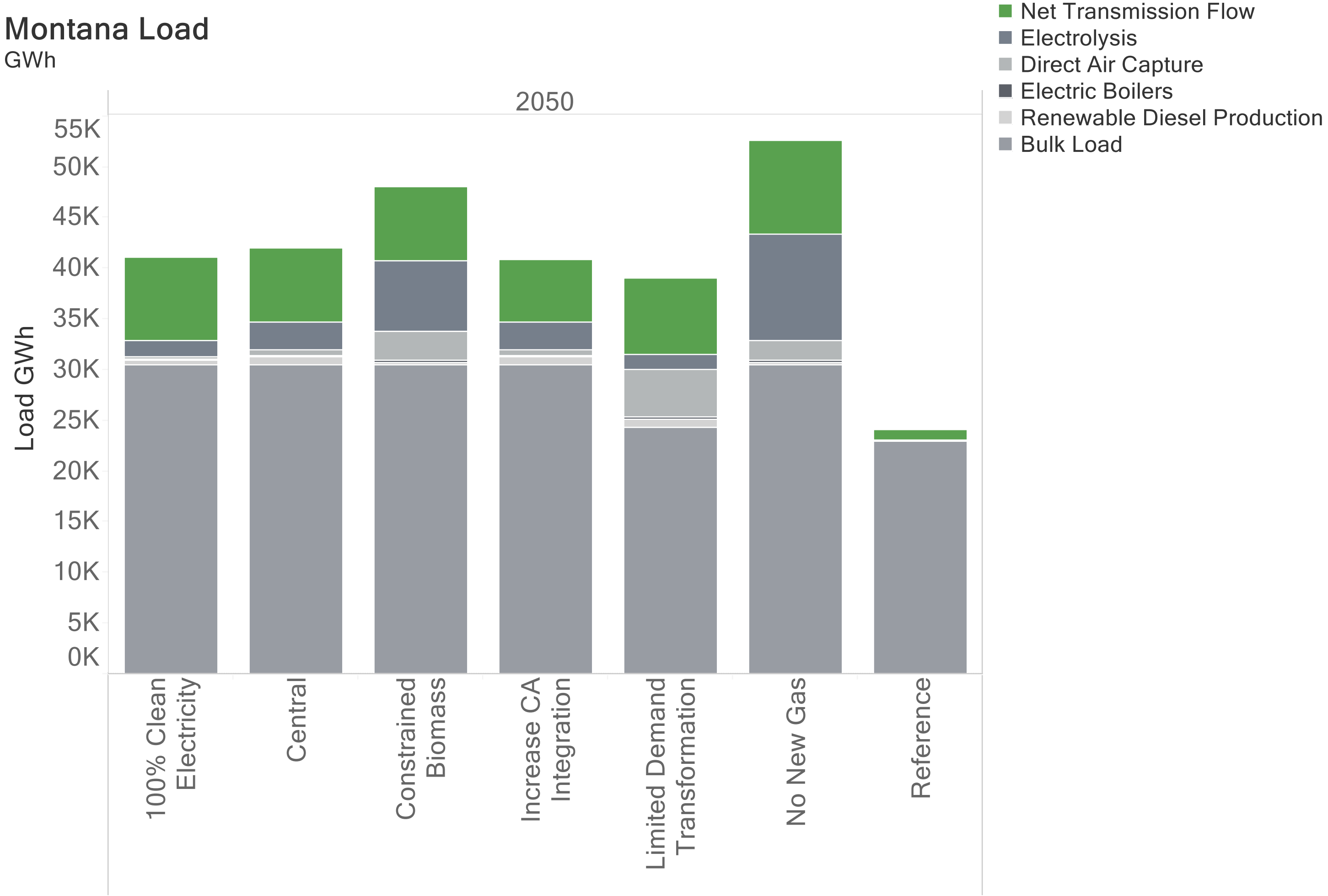
- A close to doubling of wind from 2035 to 2040 supplies out of state demand for clean energy
  - Washington State is the main export market, driven by larger transmission ties to the state
- Montana energy is majority wind by 2050
- New, tighter emissions targets proposed in Washington and other Western states since the NWDDP was conducted will drive further demand for low cost and clean Montana wind exports



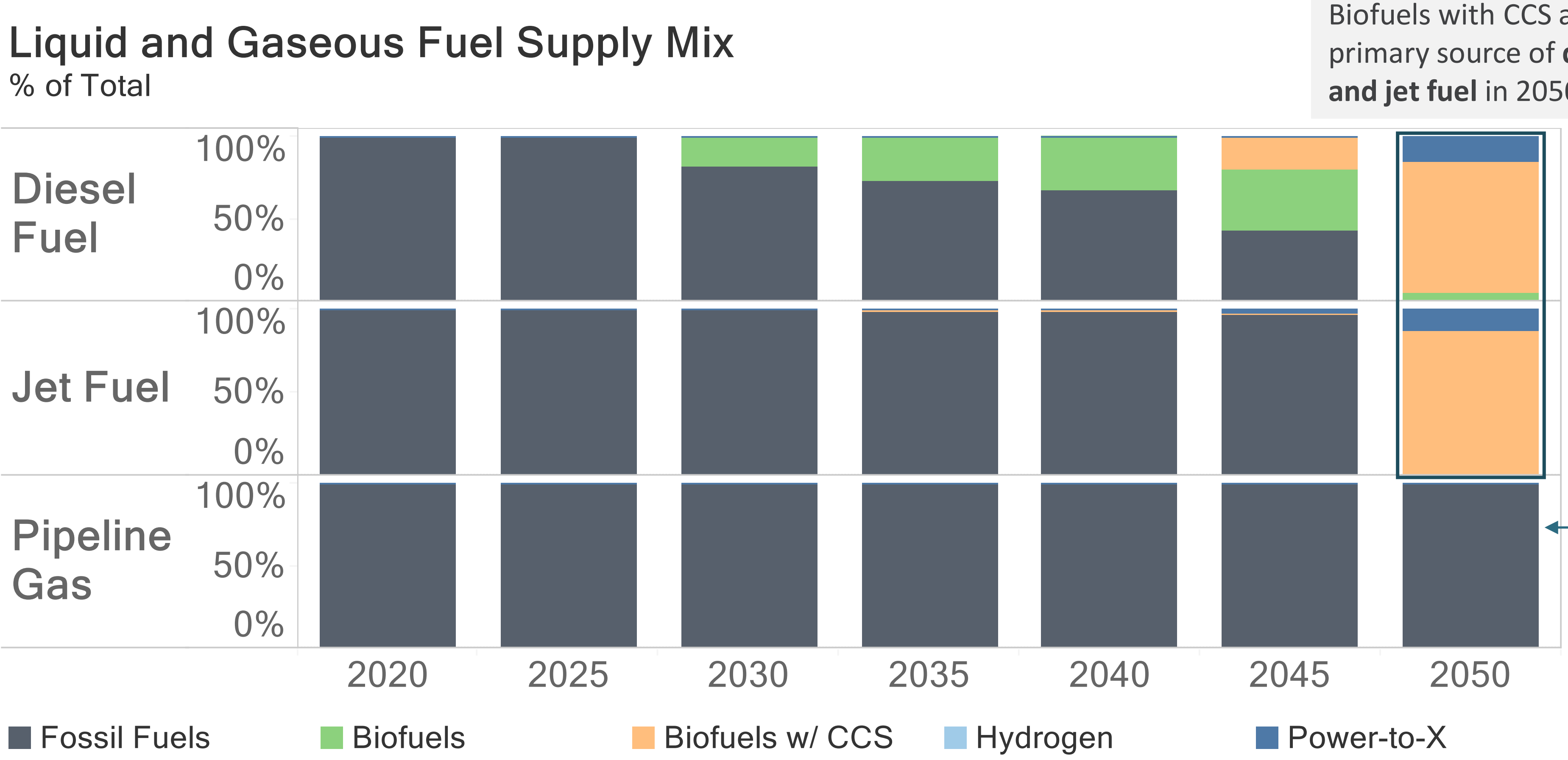
Montana's Electricity Export Market

Montana

- In all cases, Montana is a significant net exporter of electricity to other states by 2050
- Total exports are limited by the available transmission
  - 2.2 GW to Washington
  - 0.34 GW to Idaho
  - 0.6 GW to the rest of the West
- Expanding transmission to surrounding regions would increase the export market potential for Montana
  - Key opportunity to investigate in future state planning efforts



Montana Energy Supply: Fuels

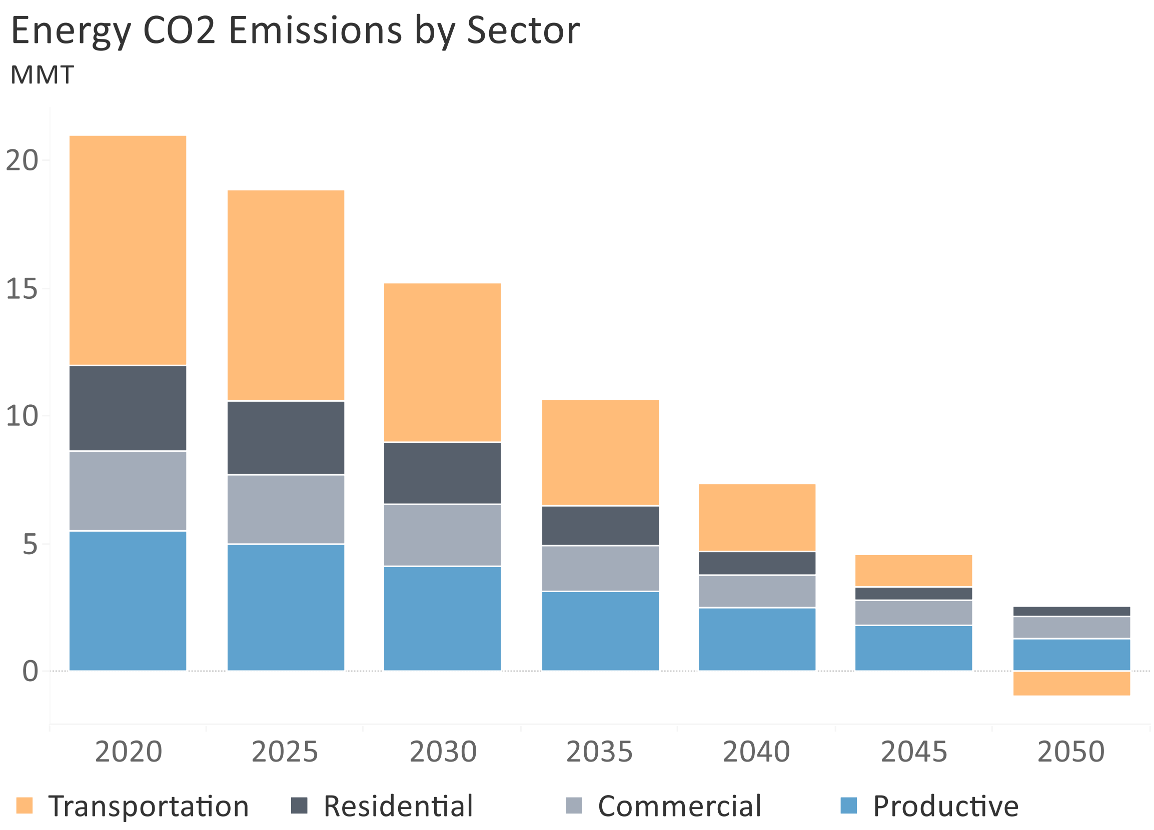


Biofuels with CCS are the primary source of **diesel and jet fuel** in 2050

While other states decarbonize a fraction of pipeline gas with synthetic electric fuels, Montana retains fossil gas, choosing instead to offset emissions with CCS

Montana Energy CO_2 Emissions By Sector

- Overall emissions decrease across all sectors of the state's economy
- Transportation emissions decline significantly with on-road (LDV, MDV, and HDV) significantly reduced
  - In 2050, biofuels with CCS are the dominant source of diesel and jet fuel, resulting in negative emissions
- Building emissions are reduced to ~1MMT by 2050 as heating services are electrified



Montana Decarbonization Modeling Key Takeaways

- The NWDDP assumptions drive final energy demand to fall by 35% through greater efficiency, much of which comes from a transition to electrified transportation and electrified end uses in buildings
  - Electricity demand rises 71%. Our studies in the West and elsewhere indicate that electrification paired with growth in clean electricity sources is a main component of cost effectively reaching net zero emissions in the future
- Montana uses its geographic strengths on the supply side in the NWDDP
  - A large wind sector is established, supplying clean energy to Montana and surrounding regions
  - Carbon is sequestered in saline aquifers in the production of liquid fuels from biomass, offsetting emissions from other sources

Caveats to NWDDP Montana Findings

There are several ways in which the NWDDP analysis cannot be directly applied to Montana

- Scenario definitions and assumptions are not tailored to Montana interests or to represent the Montana policies and uncertainties most valuable to investigate to inform policy development
  - Tailored analysis supporting state and stakeholder-driven questions will best serve state climate policy action
- Targets have changed for other Western states
  - Since the NWDDP was conducted, Western states (including Washington, Colorado, and Nevada) have set more stringent emissions and clean energy standards
  - These will drive more clean energy investment, and potentially greater demand for Montana resources
- Proposed Montana emission targets were not modeled
  - Carbon neutral electricity by 2035 and net zero emissions by 2050
  - These will drive more clean energy investment in the state than in the NWDDP
- Prices are out of date
  - Forecasted prices have been lowered for many clean energy technologies, in some cases substantially, since the NWDDP analysis was conducted in 2018. This includes for electric vehicles – one of the largest drivers of decarbonization cost reductions
- Covid-19 has impacted demand and fuel prices
  - Short-term market price impacts, and longer-term demand impacts and structural changes may revise the outlook for demand and prices over the coming years

Caveats to NWDDP Montana Findings

Continued

- No transmission expansion and limited interstate representation
  - The NWDDP did not simulate the opportunity of expanding transmission and thus expanding the market for Montana clean energy to other regions
  - Investigating this becomes more important with the move of other states towards stringent clean energy and emissions goals
- Lack of detailed consideration of Montana's coal generators
  - Policy options surrounding Montana's coal industry, including retirement schedules, were not investigated in the NWDDP
- Fuels trading limitations
  - The NWDDP did not allow states to trade clean fuels and build supply routes for clean fuel exports. This is an important pathway towards more realistic and lower cost regional decarbonization solutions
- Outdated assumptions about vehicle stock rollover
  - Assumed levels of electrification and remaining internal combustion energy stocks in the economy may not be appropriate for Montana
  - Options for trucking using fuel cells have become more viable since the NWDDP analysis was conducted. Fuel cells may play an important role in the future, particularly in long-distance trucking

Summary

What Are the Least Cost Strategies that Policy Should Target?

Northwest-wide

Energy Efficiency
MMBtu per person

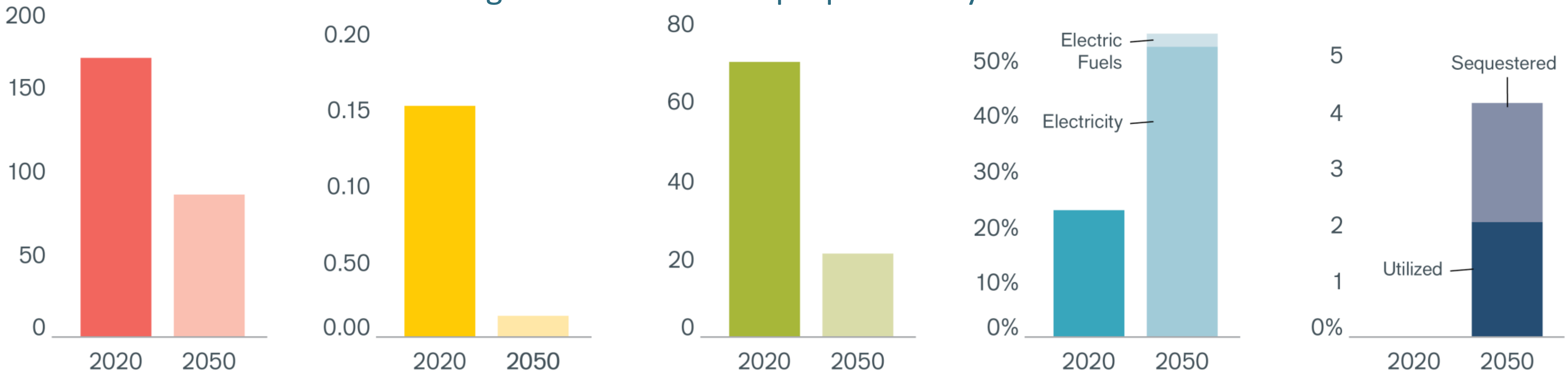
Decarbonized Electricity
tonnes CO_2 per MWh

Decarbonized Fuels
kg CO_2 per MMBtu

Electrification
Share of Total Final Energy, %

Carbon Capture
MMT CO_2 Capture

Figure for illustration purposes only



Source: Northwest Deep Decarbonization Pathways Study, June 2019, Evolved Energy Research

What Does This All Mean for Montana?

- Policy actions taken in the rest of the West could impact investments in Montana in significant ways, with opportunities to play a major export role in a decarbonized Western system
- Low cost and complementary wind resource
  - Coastal states have relatively poor onshore wind resources and import significant quantities of wind from Montana and Wyoming
- Transmission expansion
  - The NWDDP did not allow transmission expansion between Montana and neighbors. However, transmission expansion was permitted in later studies and was cost effective
  - Enables larger export market. What is the feasibility of expansion?
- Decarbonized fuels
  - Decarbonized fuels are part of decarbonization pathways across the West. Montana has low-cost resources to produce fuels and could export fuels to other states
  - Fuels are another way of exporting low-cost energy from Montana wind resources, and travel via pipeline, rail, or other forms of transport rather than electricity transmission

THANK YOU

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Methodology Appendix

High Level Description of Modeling Approach

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

Model of Western States' economy

Residential
Commercial
Industrial
Transportation

1: Model calculates energy needs

West's energy needs

Electricity
Liquid Fuels
Gaseous Fuels

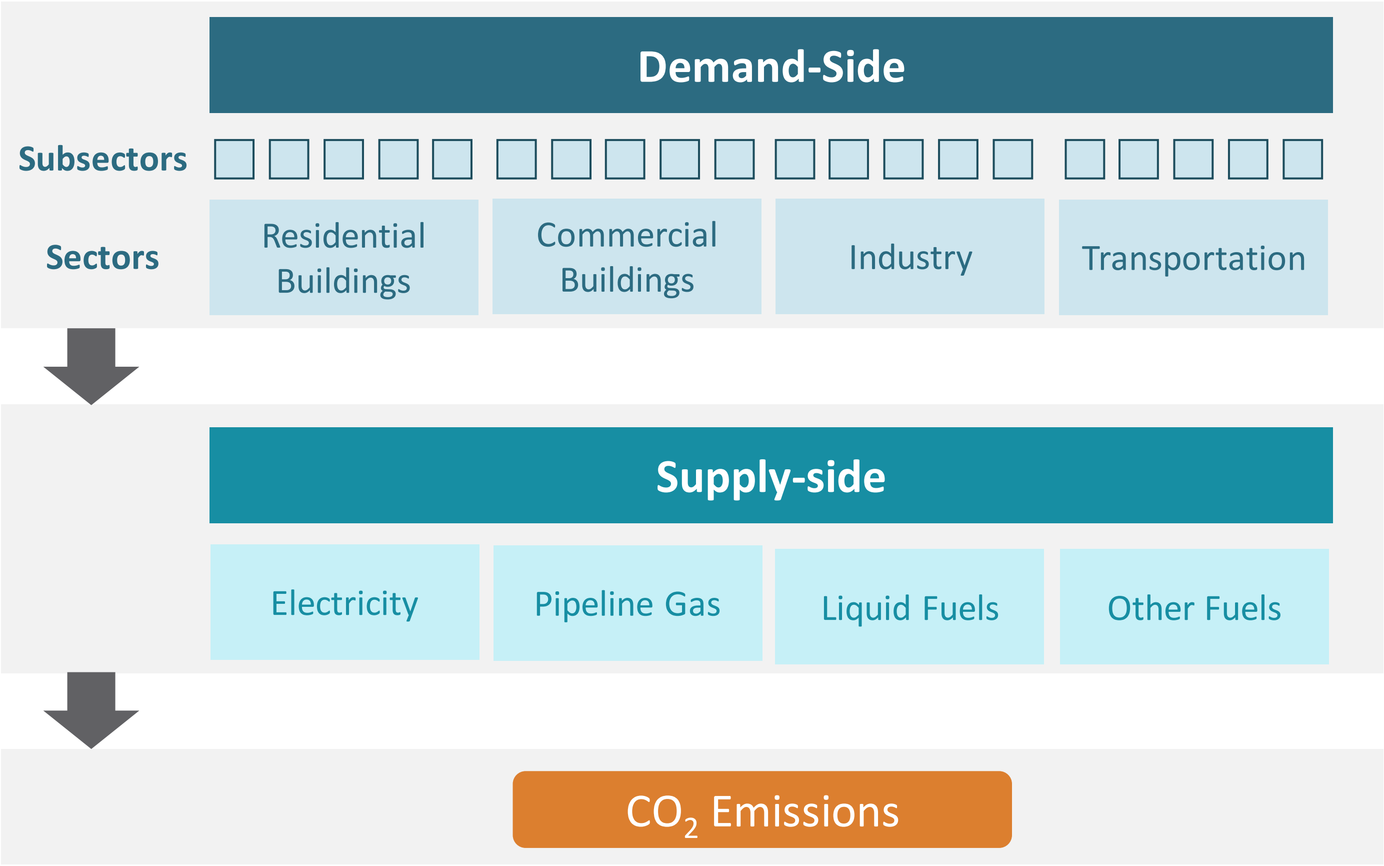
2: Model calculates energy supply

Constrained by clean energy goals

Supply energy reliably at least cost

Generation
Transmission
Storage
Fuel supply
Carbon

Analysis Covers Entire Western 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)

Demand-Side Modeling

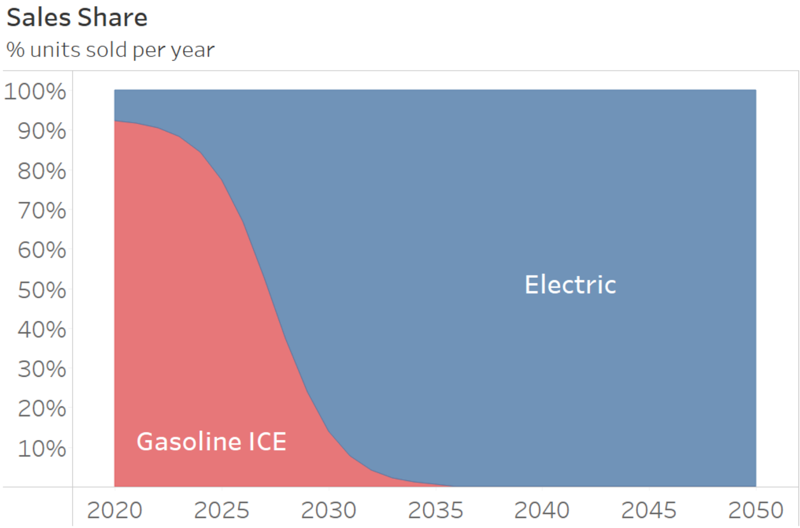
- Scenario-based, bottom-up energy model (not optimization-based)
- Characterizes rollover of stock over time
- Simulates the change in total energy demand and load shape for every end use

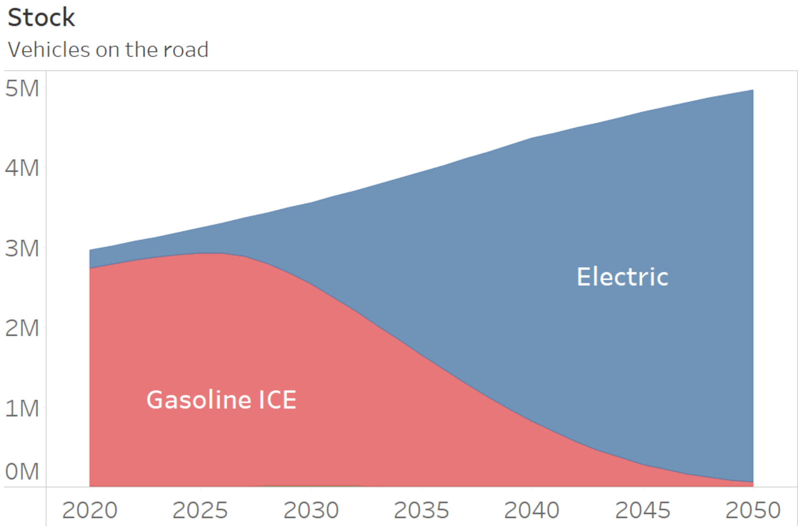
Illustration of model inputs and outputs for light-duty vehicles

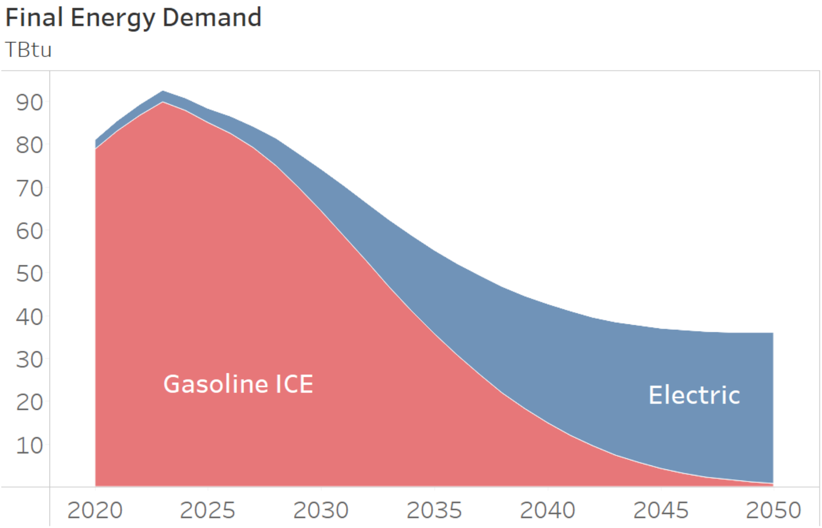
Input: Consumer Adoption
EV sales are 100% of consumer adoption by 2035 and thereafter

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







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

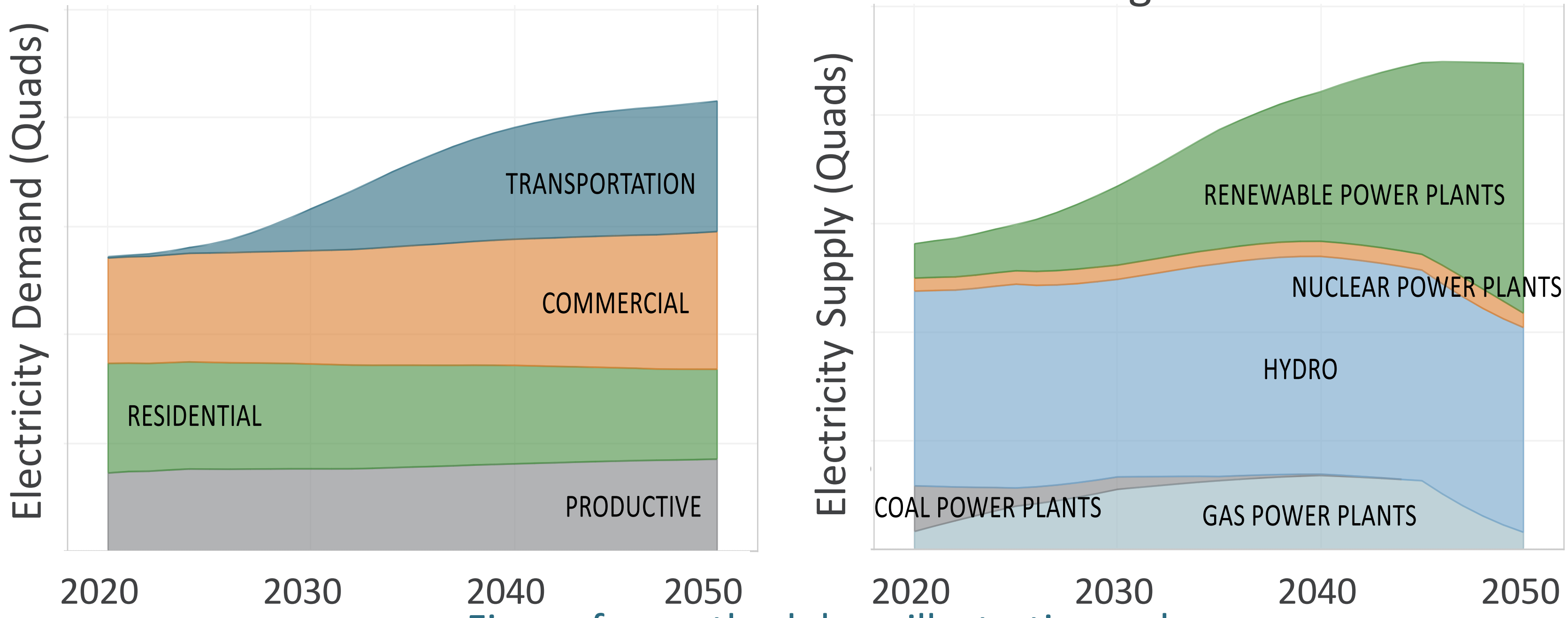
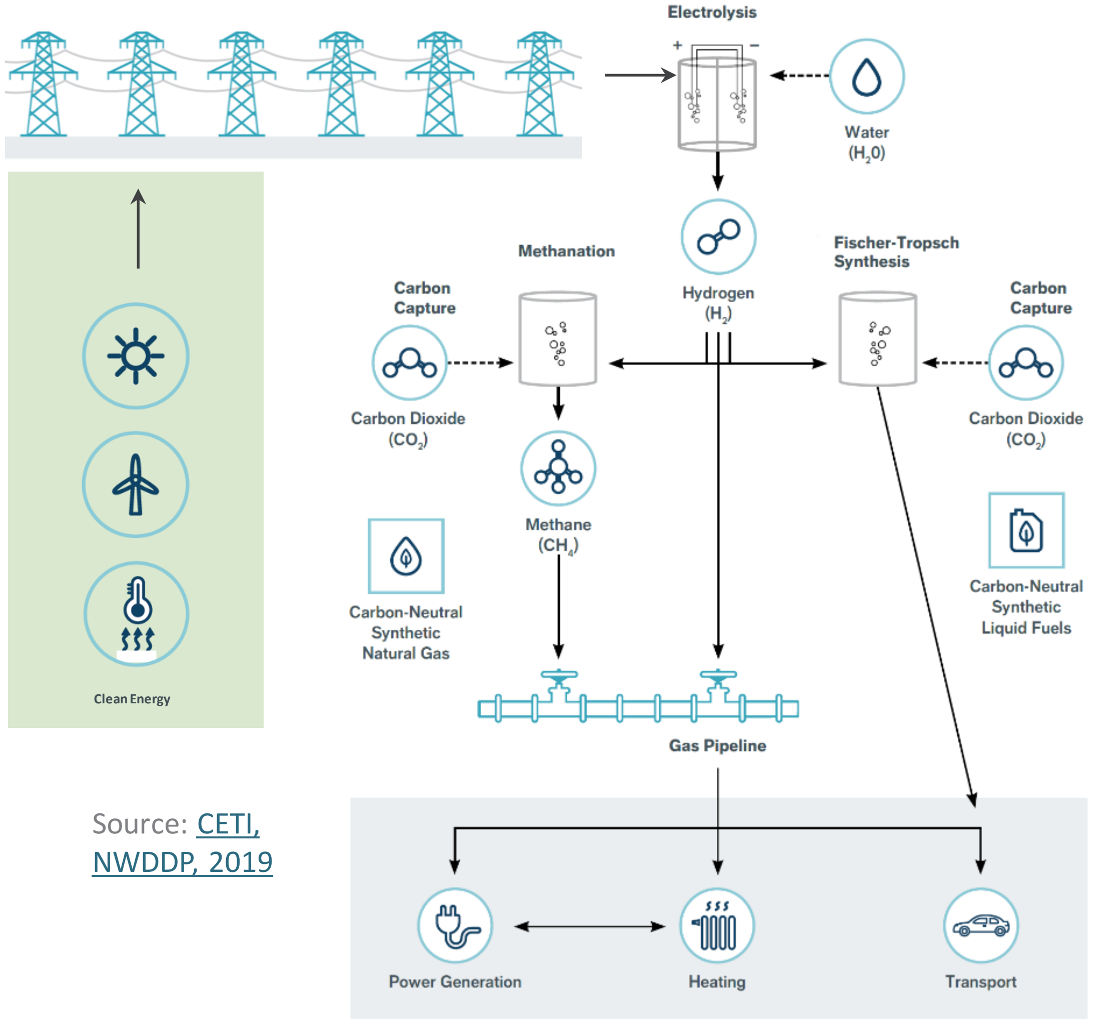


Figure for methodology illustration only

- **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

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

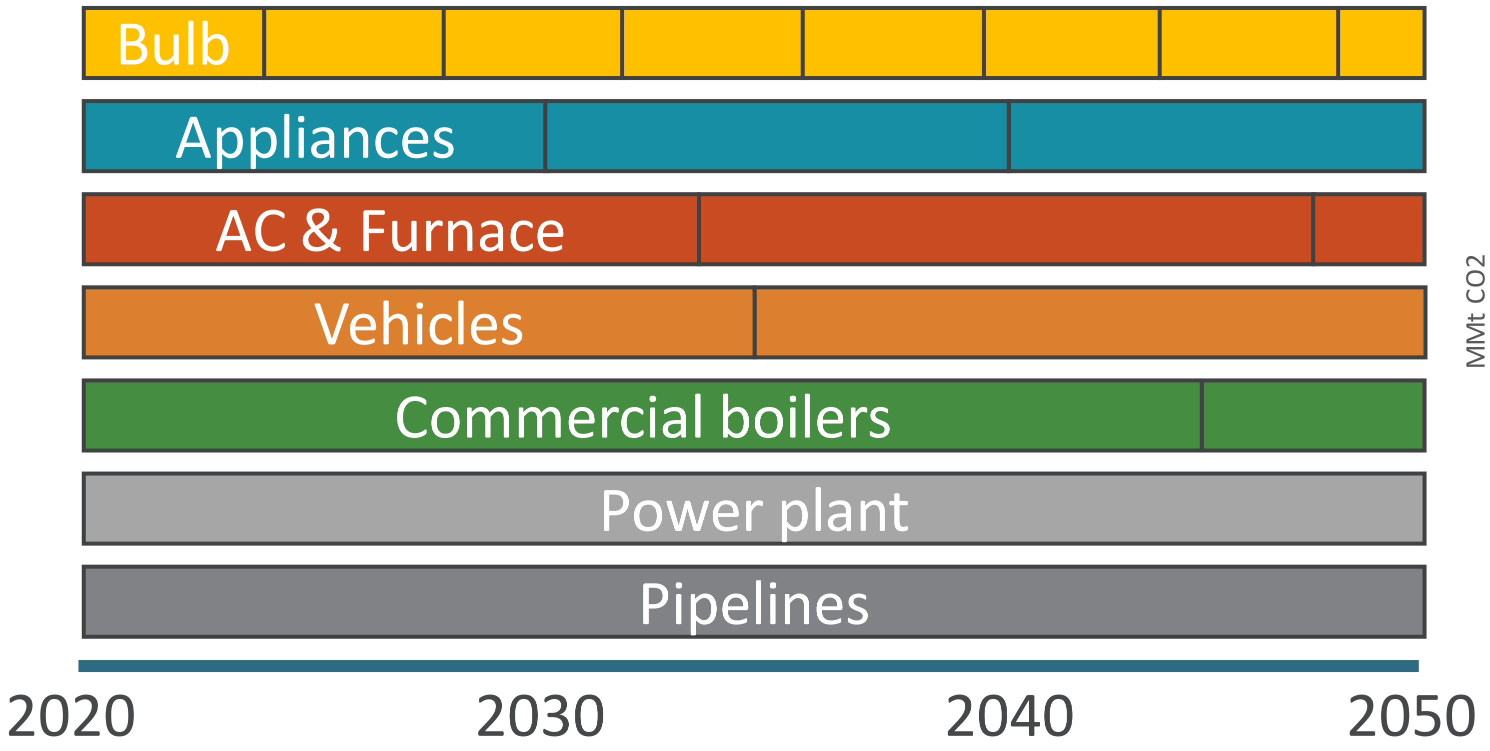


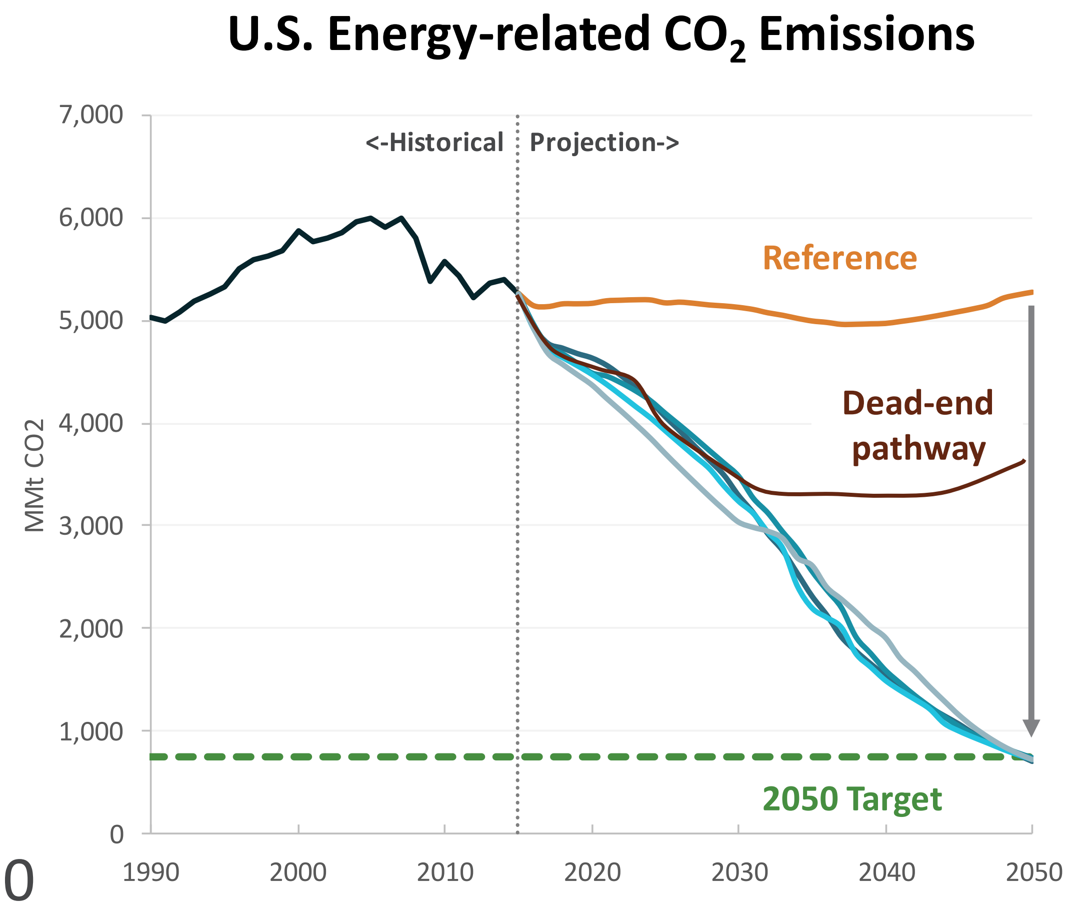
Source: CETI, NWDDP, 2019

Near-Term Focus on Long-Lived Assets

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

Stock replacement count before mid-century





WA Appendix

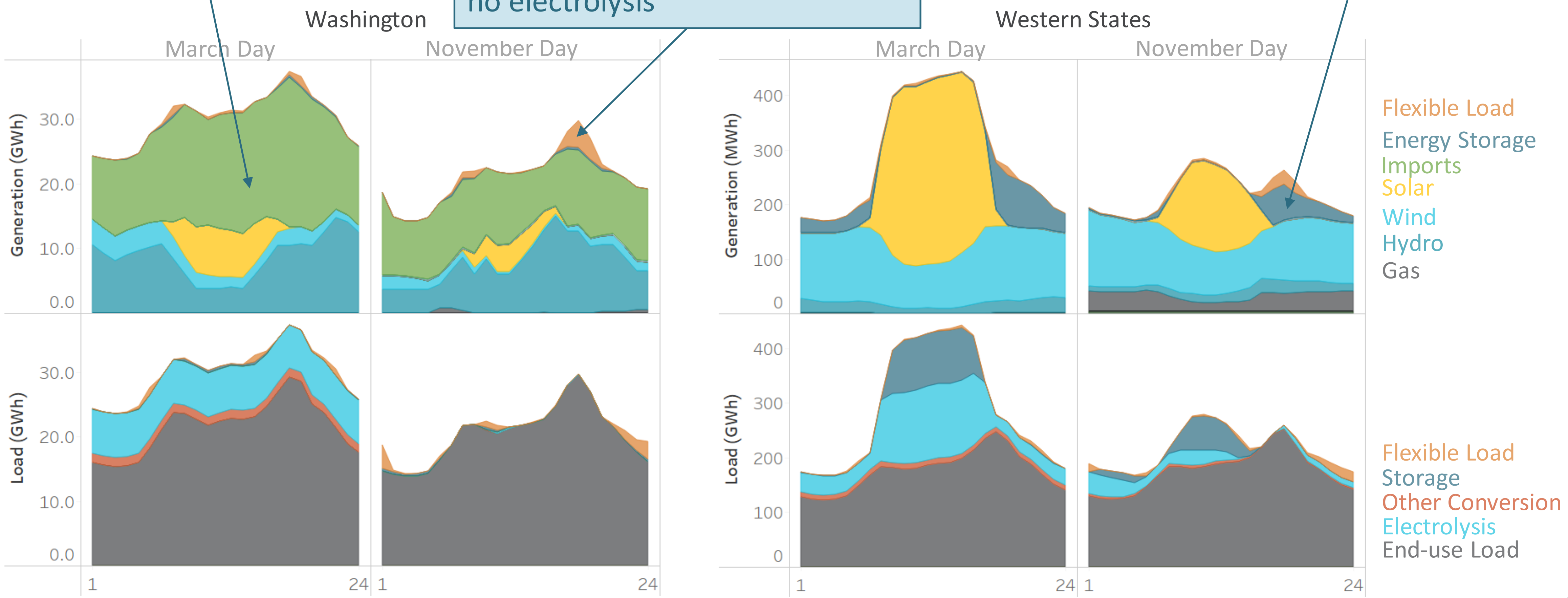
Balancing the System: High Energy and Low Energy Days in 2050

Washington relies on flexible loads, imports, hydro, and electrolysis to balance load

Unconstrained energy day in March: imports and electrolysis

Constrained energy day in November: flexible loads, clean gas generation, reduced imports, no electrolysis

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

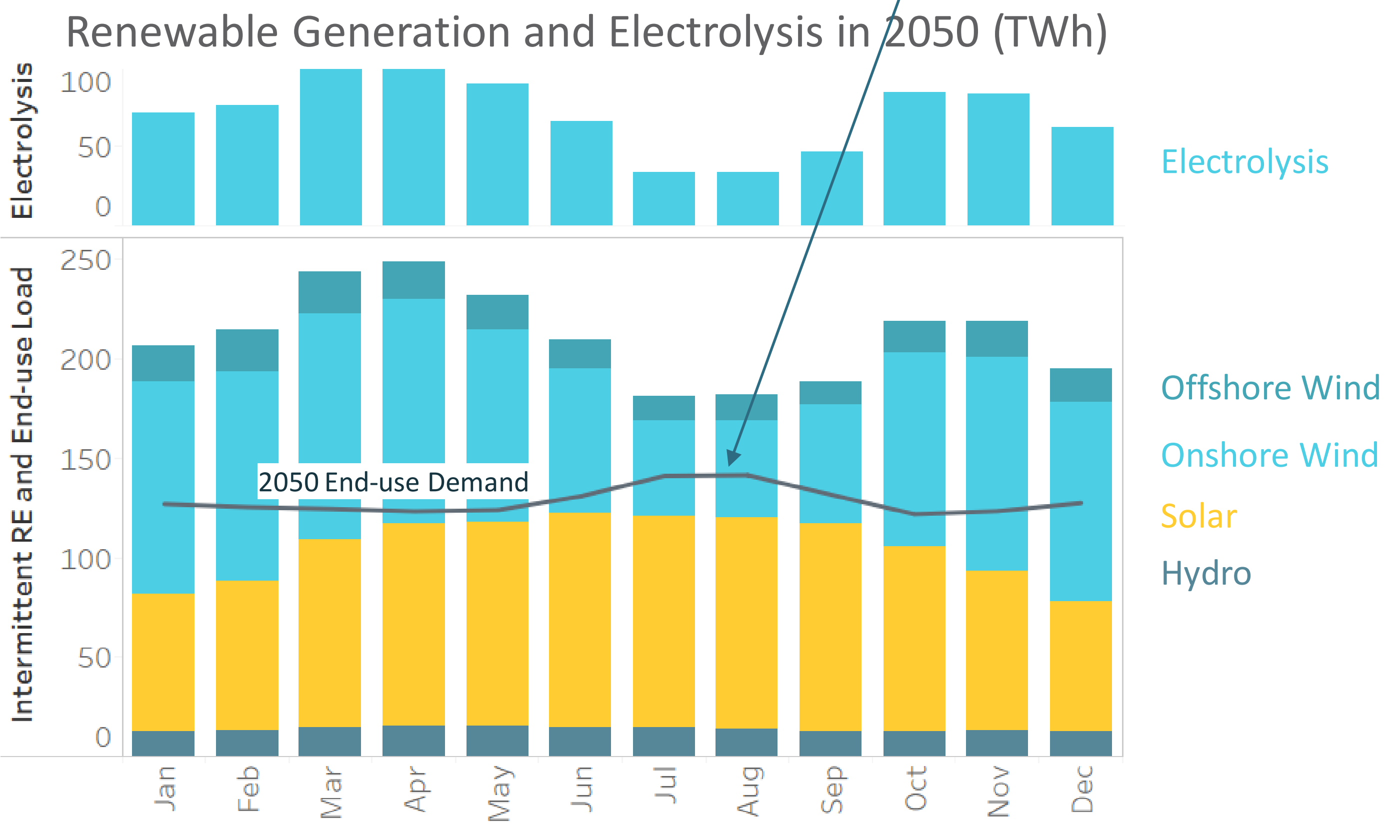


Seasonal Balancing in 2050: West Wide

Fuels production an integral part of balancing the electricity grid in 2050

- Seasonal imbalance of intermittent renewable energy availability
  - Shifting energy across seasons difficult with current storage technologies such as lithium ion
- Clean fuels demand is an opportunity for seasonal balancing
  - Store electricity in liquid fuels
- Large flexible electrolysis loads can help balance the grid over different time scales

Peak end-use demand in 2050 coincides with lowest renewable availability and decrease in fuels production



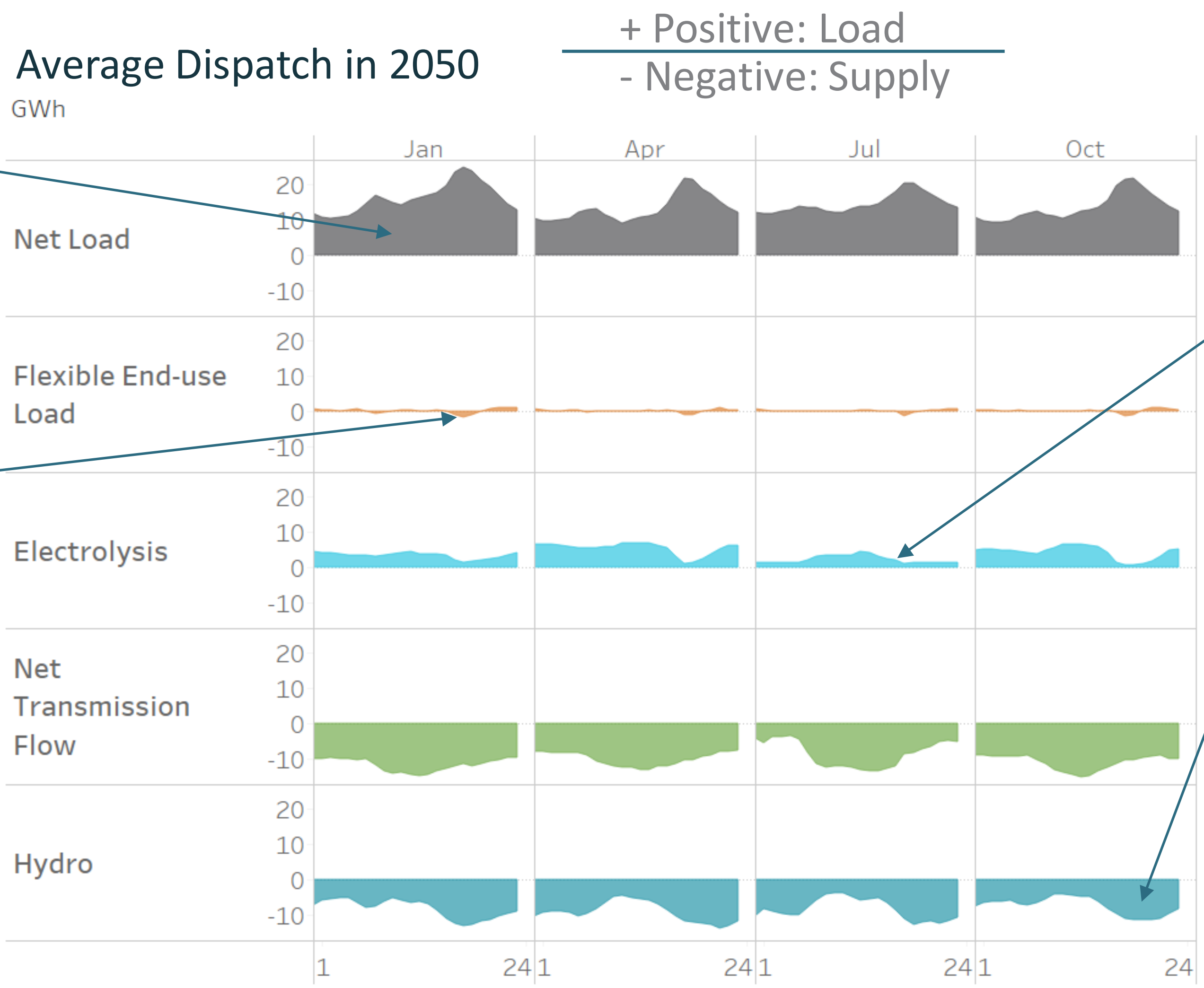
Washington's Main Balancing Resources

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

Washington loads higher in the winter in contrast to the West as a whole

Flexible loads drive down peak loads

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



Lower summer electrolysis due to reduced imports

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

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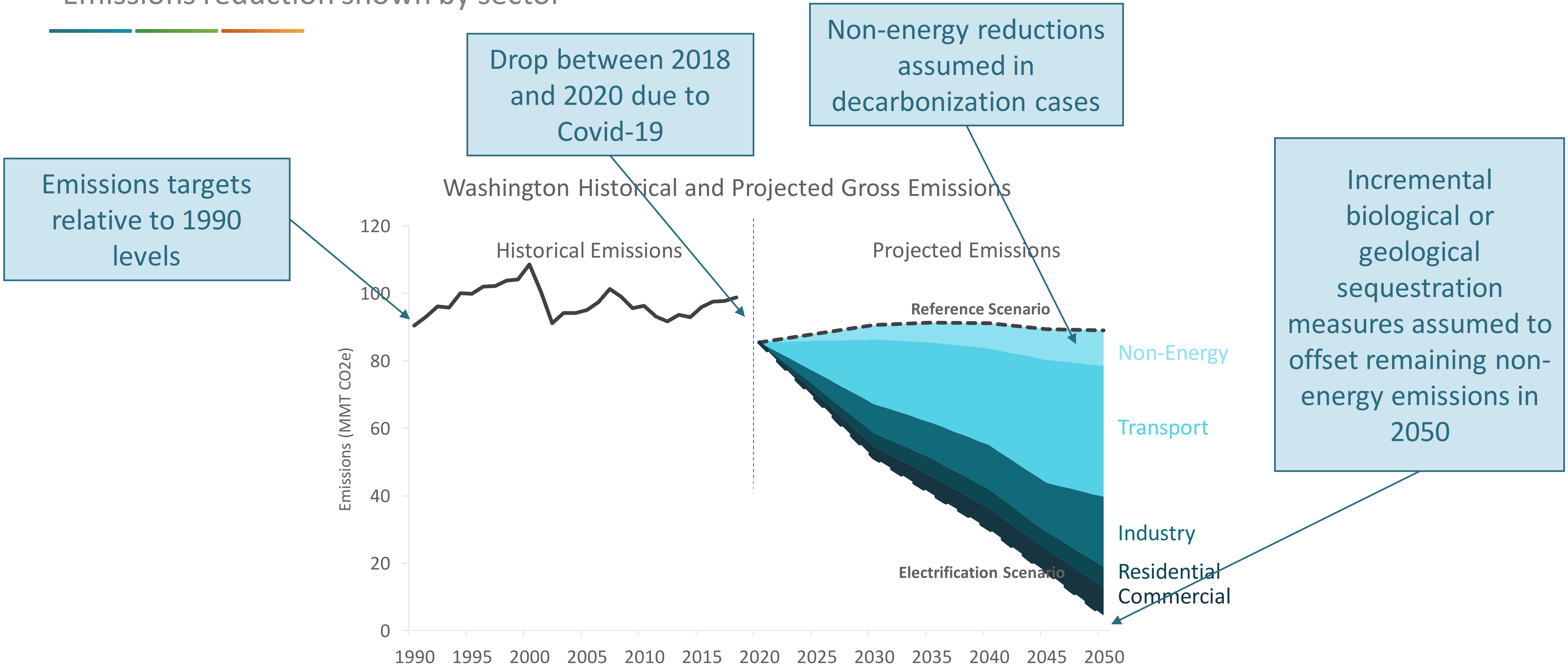
Total Gross Emissions: Reference vs Electrification Scenarios

Emissions reduction shown by sector



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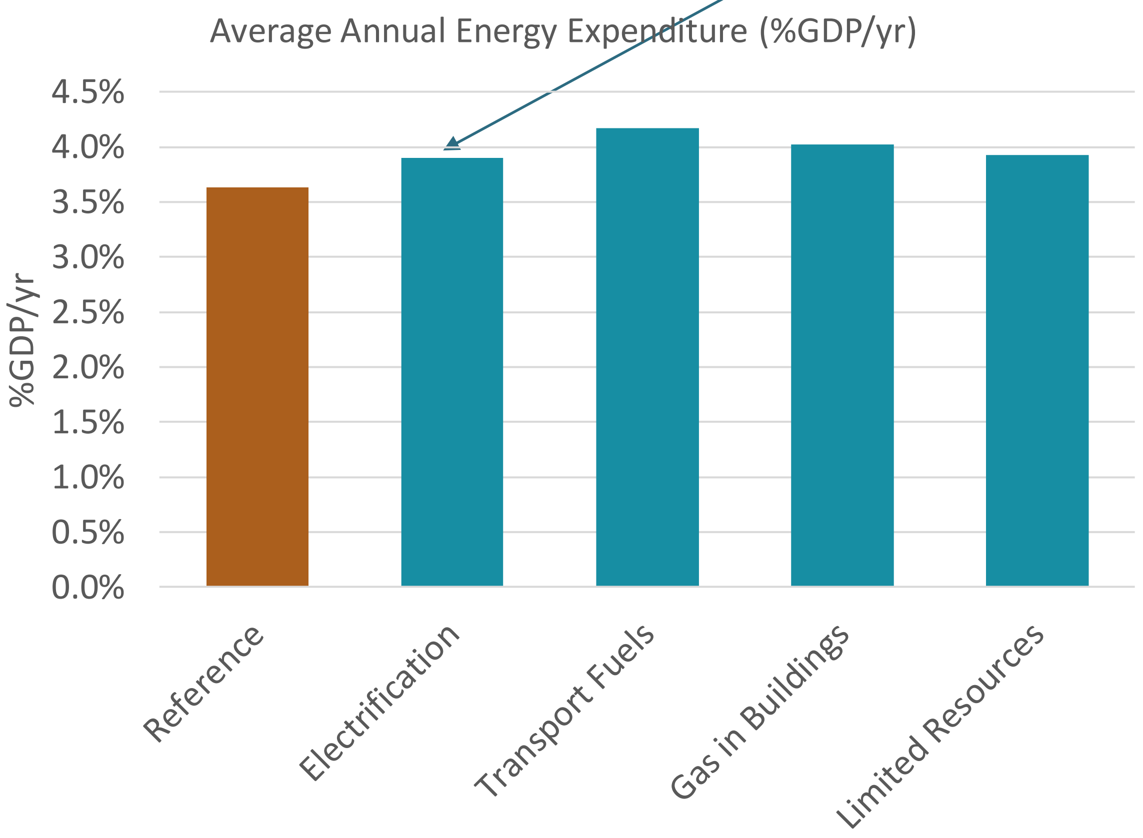
How much does Decarbonization Cost?

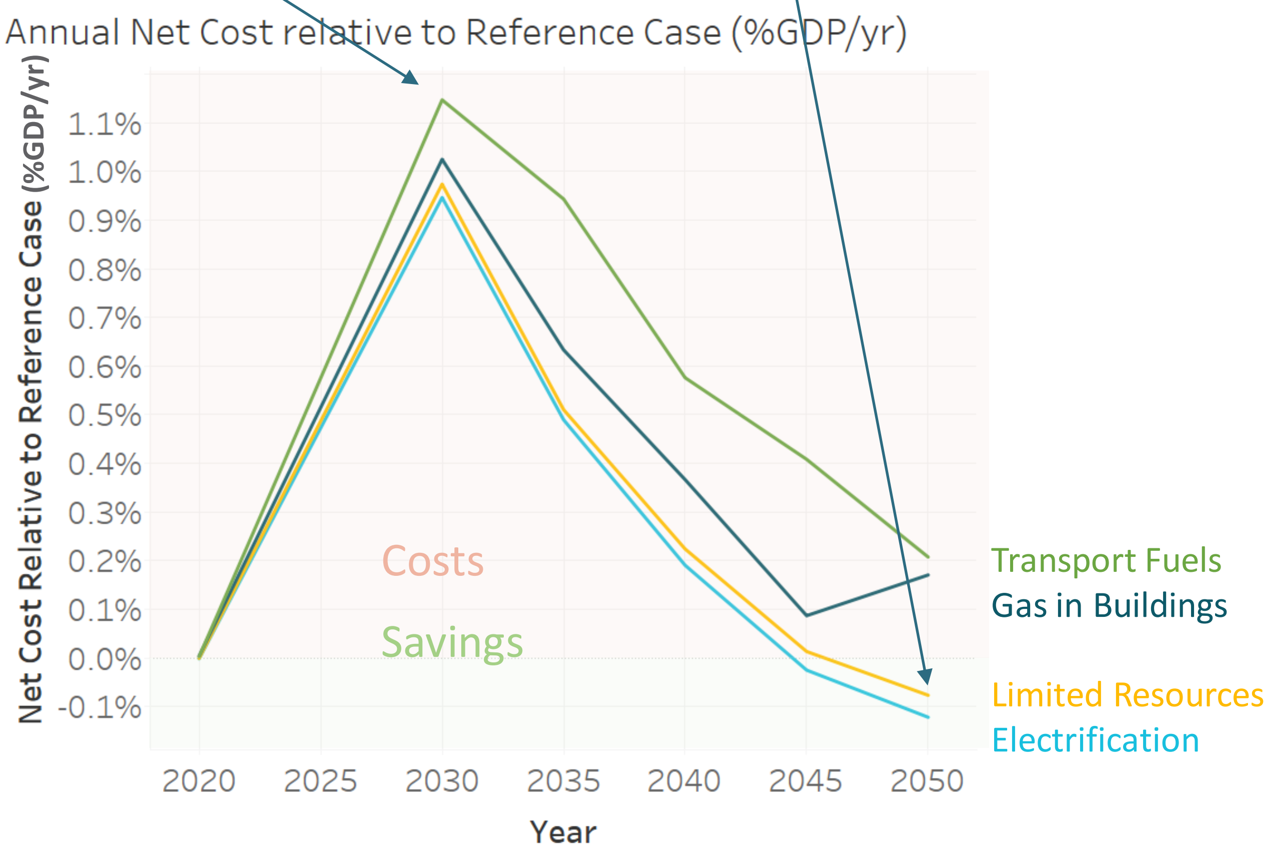
Increase in average energy expenditures vs Reference Case. Early costs followed by later savings

On average, spending slightly higher than Reference Case

Driven by increased costs to reach 2030 target

Decarbonization net benefit in the 2040s





Historical Context: Total Energy Spending as Percentage of Washington GDP

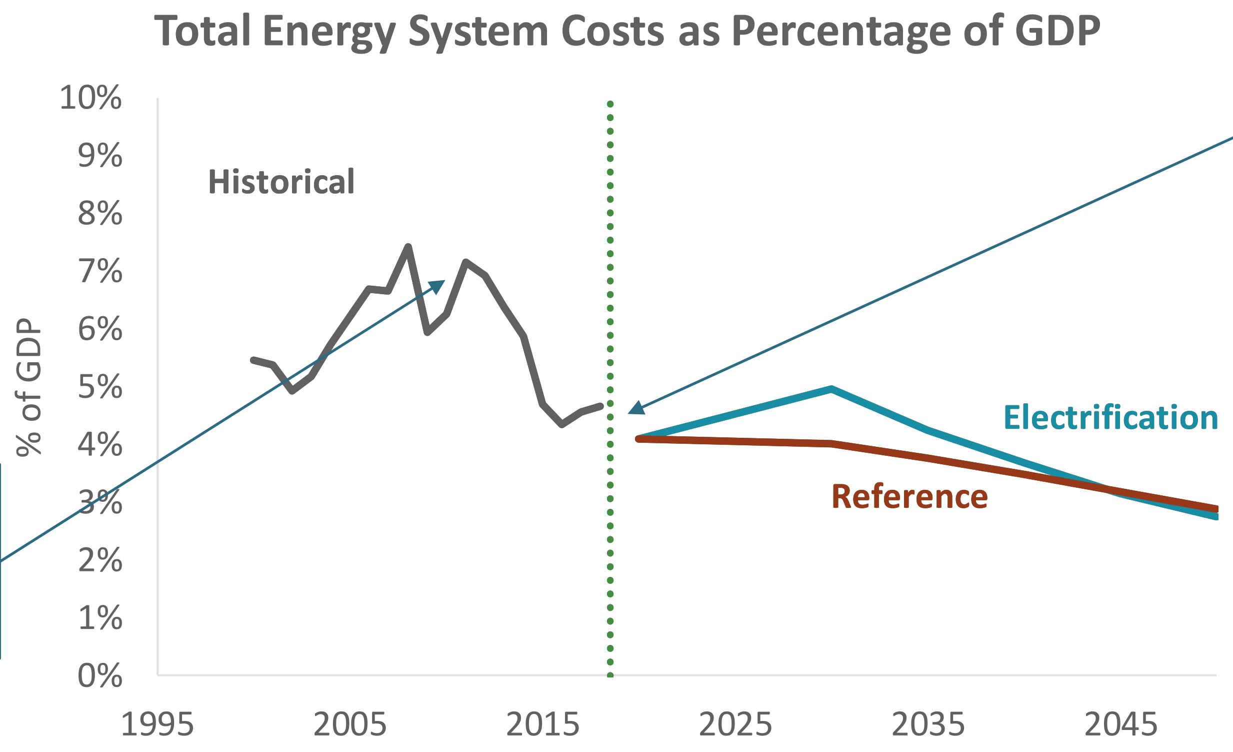
Forecasted decarbonization spending stays below historical average in all years

Decarbonization spending in Electrification Case stays below historical average in all years

Significant increase in GDP spending in the near-term with benefits in the long-term

Historical energy spending between 4-8% of GDP

Spikes in GDP from fossil fuel price volatility and the 2008 recession



Drop in % of GDP from 2018 to 2020 because of COVID: 0.3% GDP contraction* and assumed 10% drop in energy demand

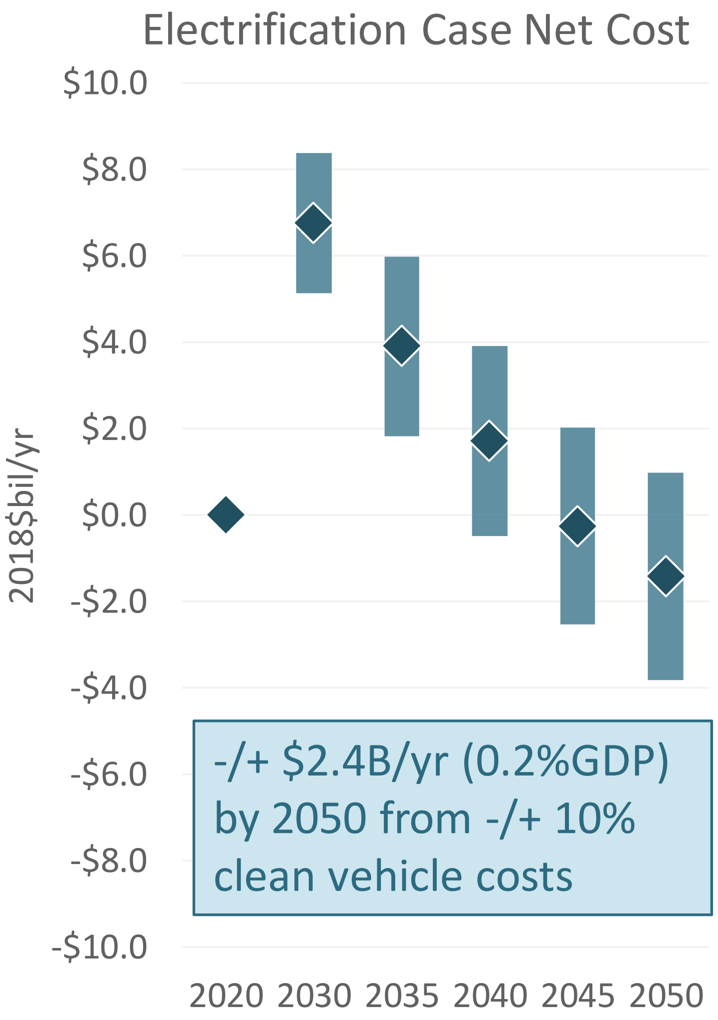
GDP rebound in 2021 of 3.9%. GDP growth rates annually of between 2% and 3%*

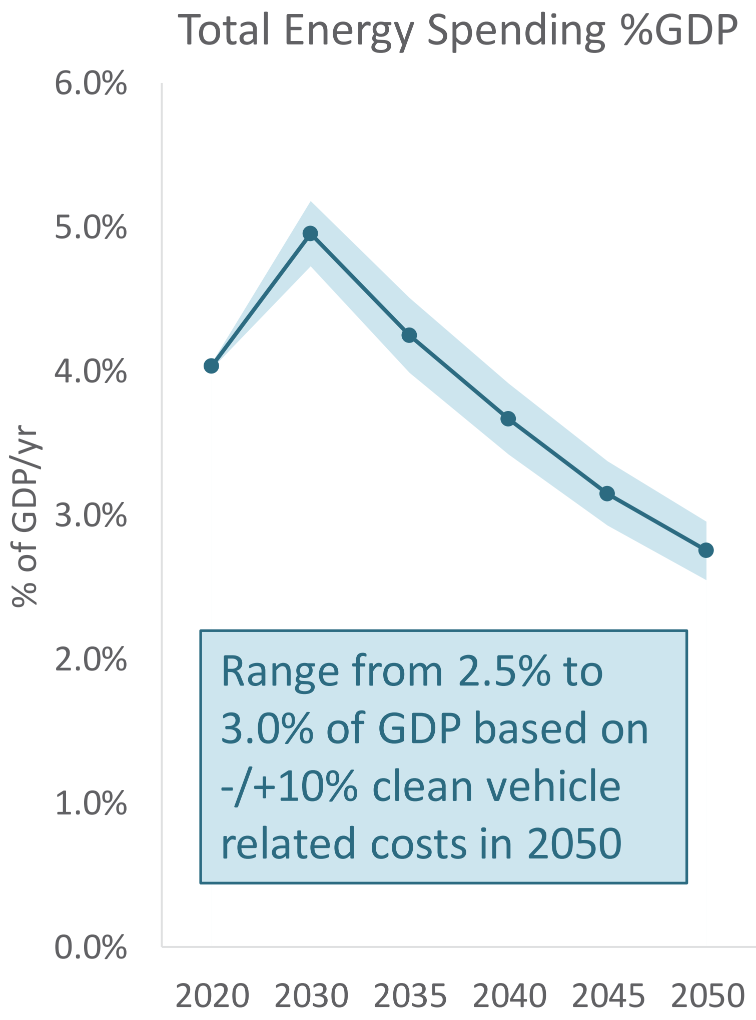
*GDP projections for Washington sourced from REMI

Uncertainty in Cost Inputs

Decarbonization costs are uncertain

- Increasing uncertainty over time
- Results are particularly sensitive to some inputs, e.g.,
  - Fossil fuel costs
  - Vehicle prices
- Example: +/-10% on clean vehicle and vehicle infrastructure costs (EVs and hydrogen)
- Decarbonization acts as hedge against fuel prices from volatility in international markets





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OR Appendix

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 other states
  - Meeting targets is easier with Oregon coal retirements
  - Valuable offshore wind resource