Oregon Energy Strategy Technical Report

2/12/2025

Prepared for:

Oregon Department of Energy

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Modeling Framework

Key Study Questions

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0. What are the key elements of a least-cost pathway to meeting Oregon's energy policy objectives?
1. What if energy efficiency and building electrification is delayed by 10 years?
2. What if full transportation electrification of medium- and heavy-duty vehicles is delayed 10 years, from 2040 to 2050?
3. What if there is limited demand response participation?
4. What if there is limited utility-scale electricity generation in Oregon?
5. What if there are higher levels of rooftop solar and behind-the-meter storage and transmission is limited to reconductoring only (no new build)?
6. What might an alternative portfolio of flexible resources for electricity reliability look like?

Sensitivity Questions

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- **0a. No Change in VMT in Reference Scenario**
  - What if per capita vehicle miles traveled (VMT) remained the same from the present until 2050 instead of a 20% reduction in VMT per capita in light duty vehicles in the Reference Scenario?
- **0b. 50% Lower Tech Load Growth in Reference Scenario**
  - What if electricity demand supplied for data center and technology growth were 50% lower than the 2029 Northwest Power and Conservation Council's Power Supply Adequacy Assessment 2029 mid-higher forecast?
- **0c. No Advanced Clean Trucks Regulation in Delayed Transportation Electrification Alternative Scenario**
  - What if there were no electrification targets for medium-and heavy-duty vehicles through 2035 that deferred transportation electrification further than Scenario 2, Delayed TE?

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Modeling Methodology

Economy-Wide Energy Modeling

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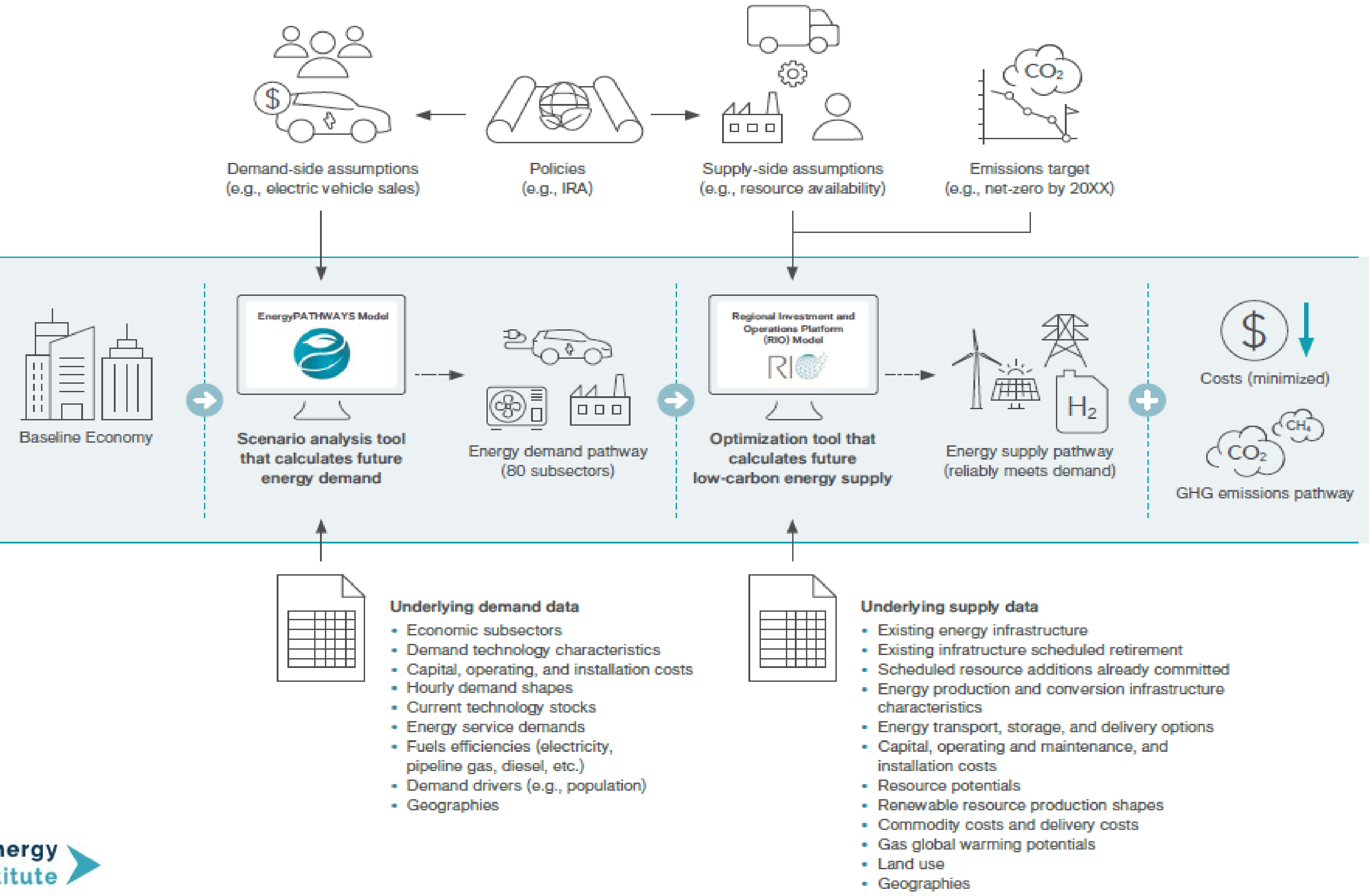
Scenario Assumptions
Model incorporates assumptions about demand-side uses, clean energy policies and incentives, and supply-side resources.

Energy Modeling
Evolved Energy Research uses two models to calculate the least-cost way to provide energy under an emission target: Energy Pathways for demand and RIO for supply.

Best Available Data
Model incorporates relevant and up-to-date energy data from reputable sources, substituted with local data where possible.



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Clean Energy Transition Institute

Modeling is Structured to Comply with Oregon Laws

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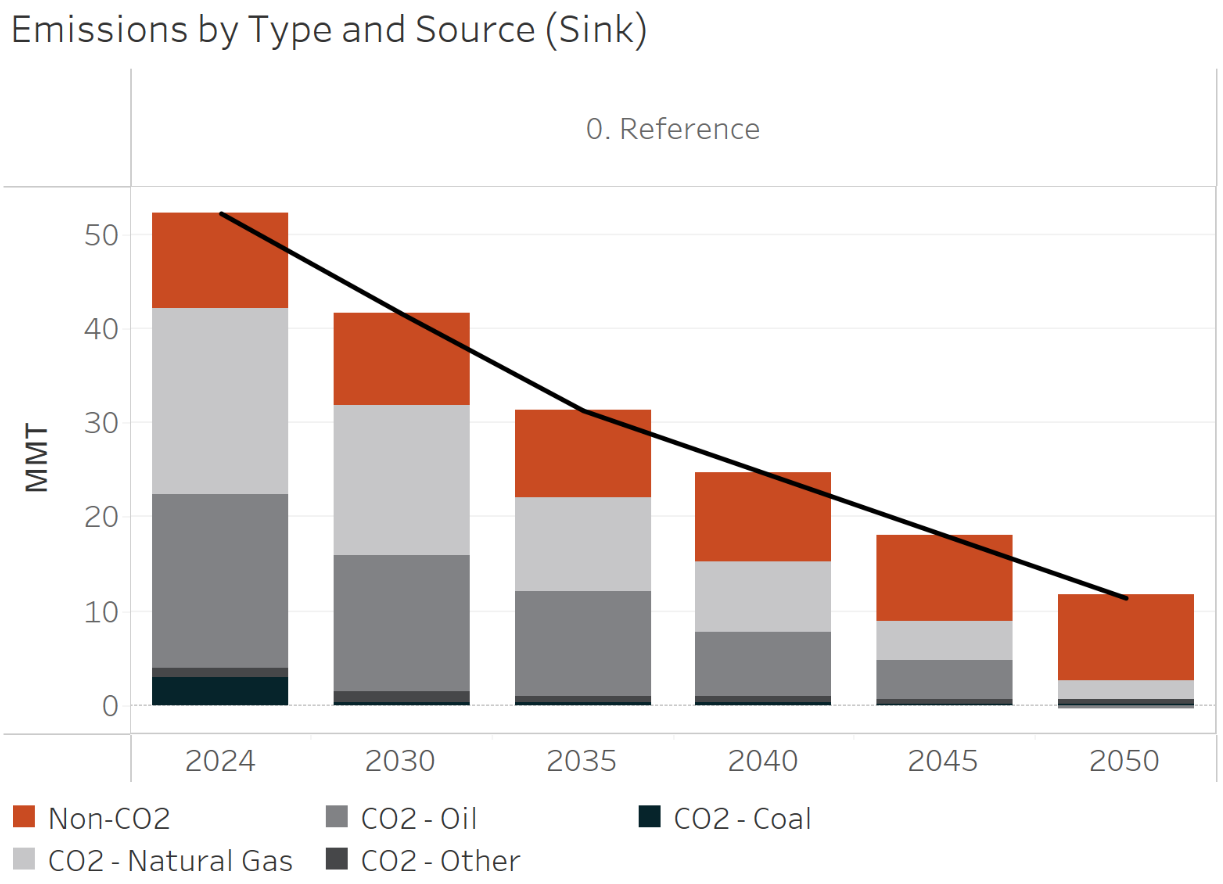
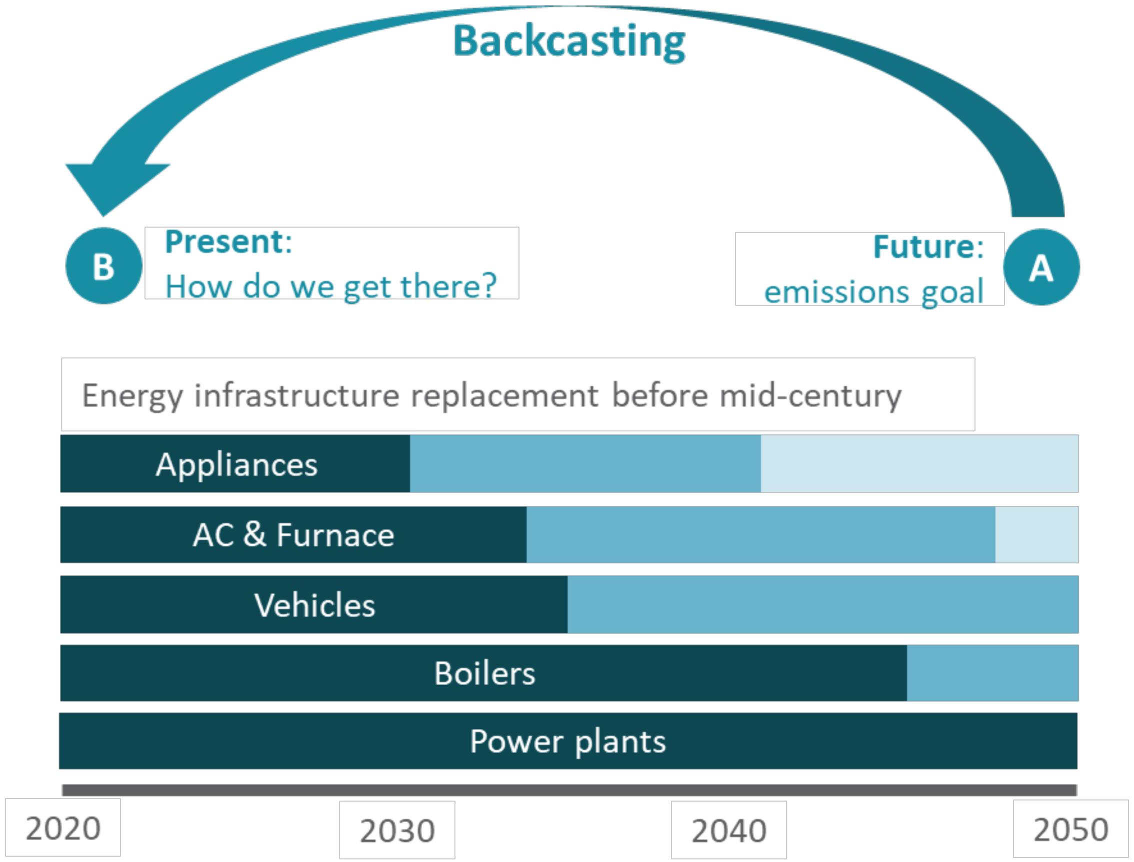
- Oregon has aggressive climate policies and goals, including 80% reduction in greenhouse gas emissions economy-wide by 2050
- Each modeled scenario shows a pathway to achieving our goals
- Nearly all emission reductions come from energy sector



Note: Analysis was undertaken using the Climate Protection Program as proposed.

Forecasting vs. Backcasting

- **Forecasting**: project changes based on expected customer behavior given incentives/technology
  - e.g., result of current policy
- **Backcasting**: start with an end-point and work backwards to infer customer adoption over time
  - What is the best path to be on?
  - Target for future policymaking: Where is current policy falling short?
  - All options available in the long term



Sector Coupling: Challenges and opportunities

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- Economy-wide approach needed to plan for electricity and clean fuels growth and operations when targeting Oregon's emissions targets
  - What are the regional implications of fuel and electric sector coupling?
  - Future-proof investments and manage risk by understanding new opportunities and speed of change
- Make decisions in an economy-wide, temporal, and spatial context
  - Explore the tradeoffs between strategies that incorporate load growth, clean fuels, carbon management, electrification opportunities, and new industry
  - Chicken and egg: What comes first, what are the barriers to development, where should near-term efforts be focused?
  - Whack-a-mole: Doing less in one part of the economy requires more in another, understand cost and feasibility consequences of decision making

Reference Scenario Database Development with Oregon-Specific Data

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- Oregon-specific data collected from up-to-date Oregon datasets, past studies, and consultations
  - Transportation Data (ODOT, EPA MOVES)
  - Building Data (NEEA RBSA & CBSA, EIA RECS & CBECS)
  - EIA State Energy Data System (SEDS)
  - Oregon DEQ GHG Emissions Inventory
  - Planned resource investments
  - Data center and crypto forecast data
  - PSU Population Research Center
- Review of Oregon resources and input from ODOE and data holders in identifying available datasets

Model Geography: Oregon in Context of the West

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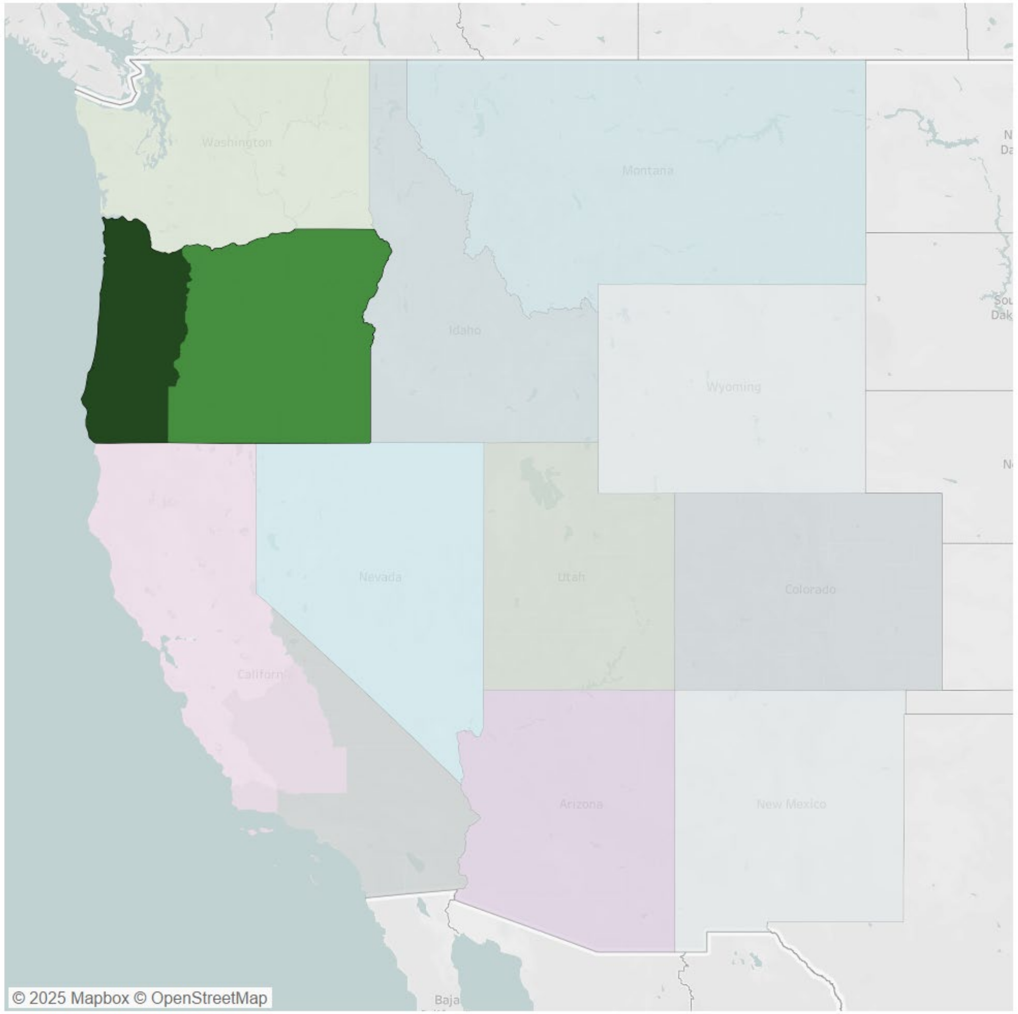
- Oregon modeled as part of larger energy system
- All states in the West modeled with their specific energy policies
  - Resource and load diversity
  - Resource competition for Oregon
- Oregon modeled as two zones: East and West of the Cascades
- Transmission between zones modeled with existing transmission capability and the opportunity to expand with an associated cost



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Sector Insights

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Electricity Sector Insights

Oregon Needs More Electricity Infrastructure

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- Even with aggressive levels of energy efficiency, the electricity sector must expand significantly to remain reliable
- HB 2021 drives near-term decarbonization but EO 20-04 requires action beyond HB 2021
- There are competing priorities with in-state and out-of-state resource development, and a diverse mix of resources is likely the least risky approach

Credit: Paulo Esteves https://stock.adobe.com/images/maintenance-in-a-high-voltage-electrical-substation/564704152

Increasingly Clean Electricity Meets HB 2021 Targets and Helps Achieve EO20-04

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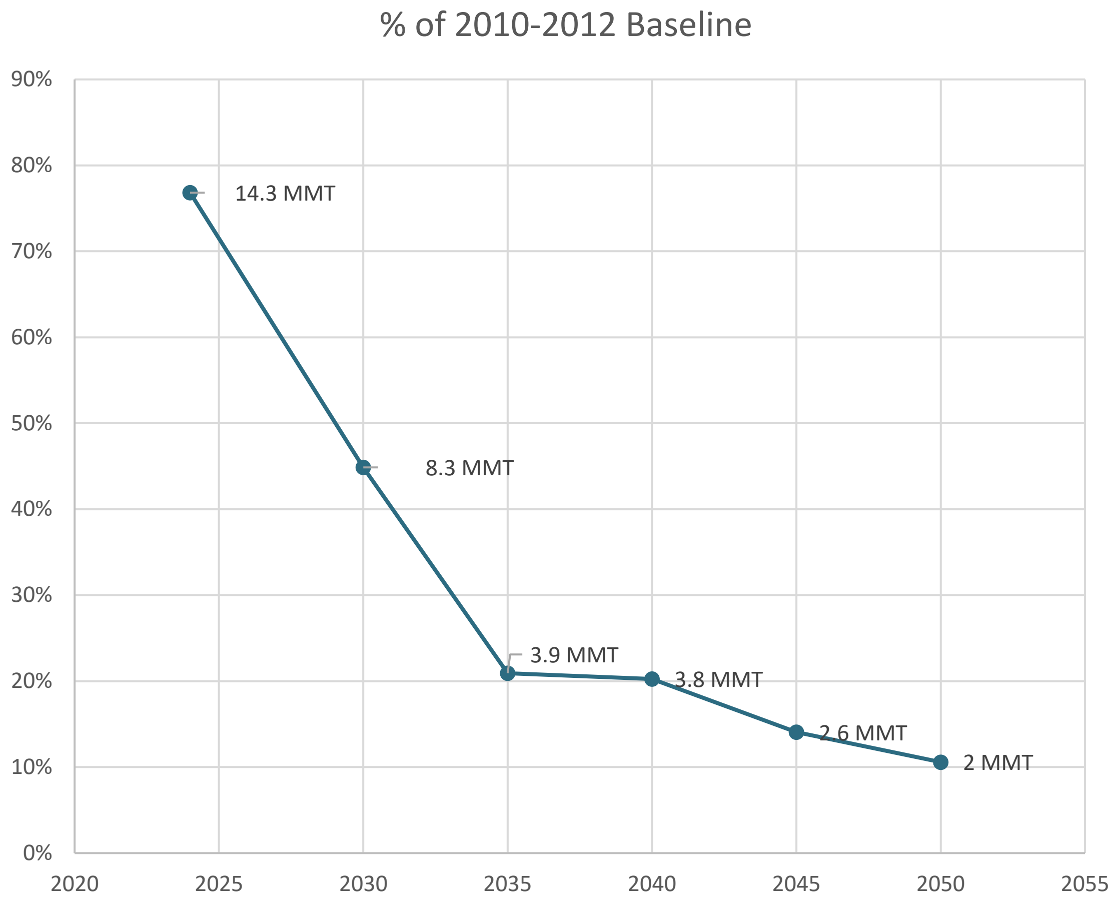
- HB 2021 targets 80% emissions reductions by 2030, 90% by 2035, and 100% by 2040 below a 2010-2012 baseline for PacifiCorp, Portland General Electric and ESSs (62.1% of load*)
- New tech loads otherwise allowed to consume emitting electricity
- EO 20-04 requires reductions beyond HB 2021 alone

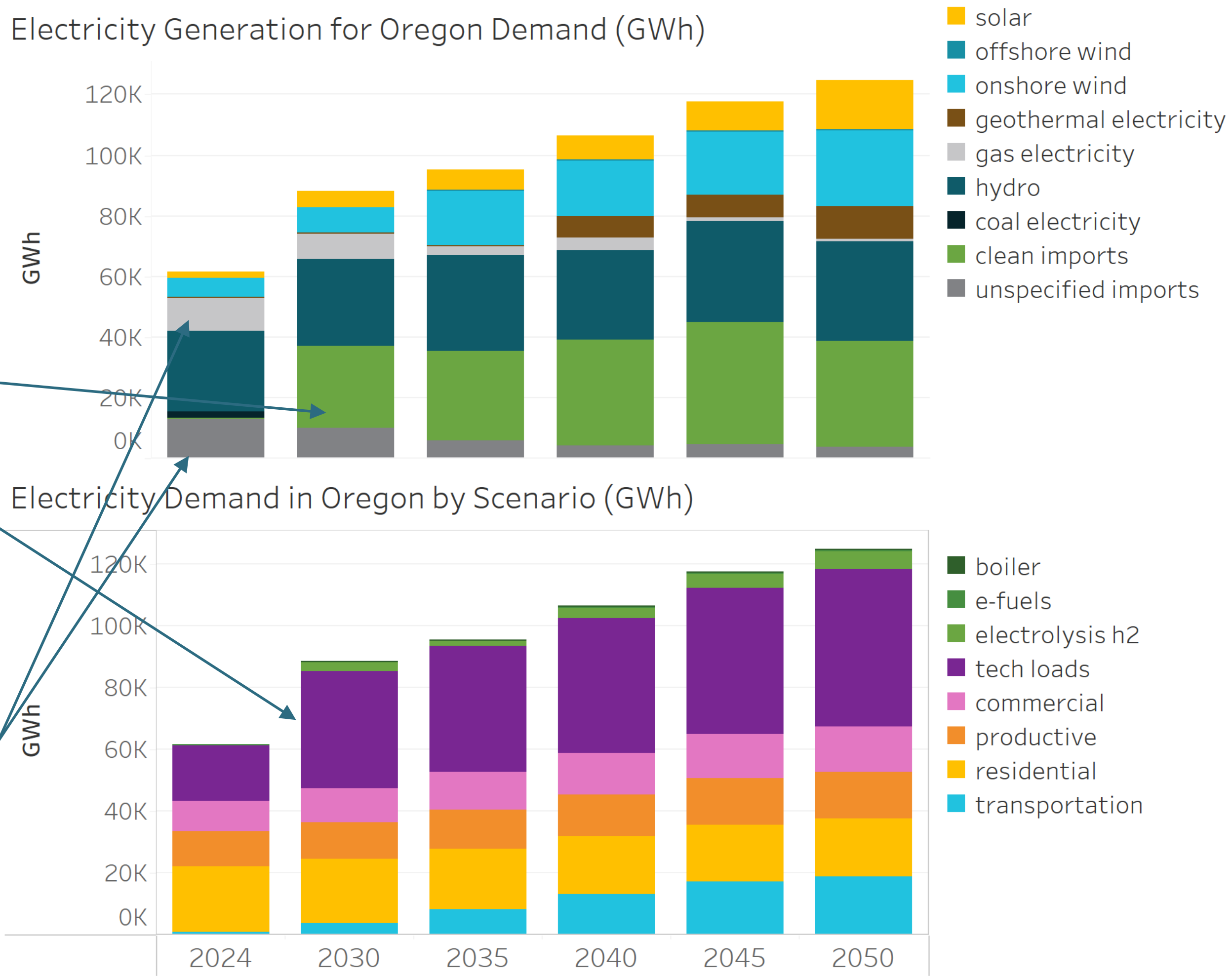


*2023-Oregon-Utility-Statistics-Book.pdf

Reference Scenario Electricity Balance

Growth from data centers and electrification met with imported clean energy and increasing Oregon capacity

In-state gas generation and unspecified imports decrease as HB 2021 and EO 20-04 drive a cleaner electricity sector

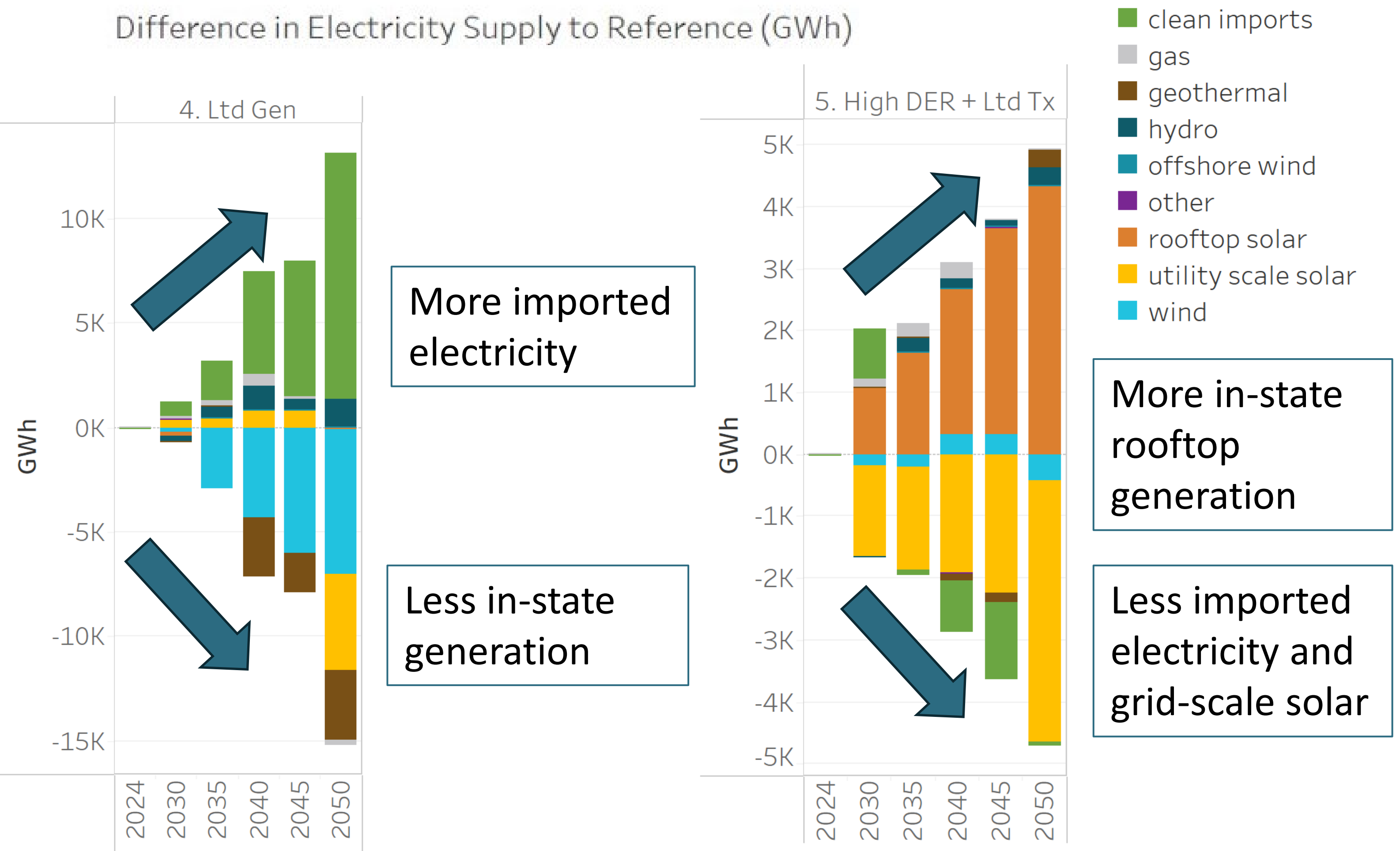


Near-term demand for clean electricity requires near-term action.

When the model selects a resource, it comes online and all development planning is assumed to have already been completed.

The Balance of In-State vs. Imported Generation Can Change

- If we cannot build more in-state generation, we need to import more (using more transmission capacity)
- If we cannot import more (due to lack of transmission capacity), we have to build more in-state
- Both alternatives cost more than the Reference Scenario



Modeling is Structured to Reflect Land Use and Natural Resource Constraints

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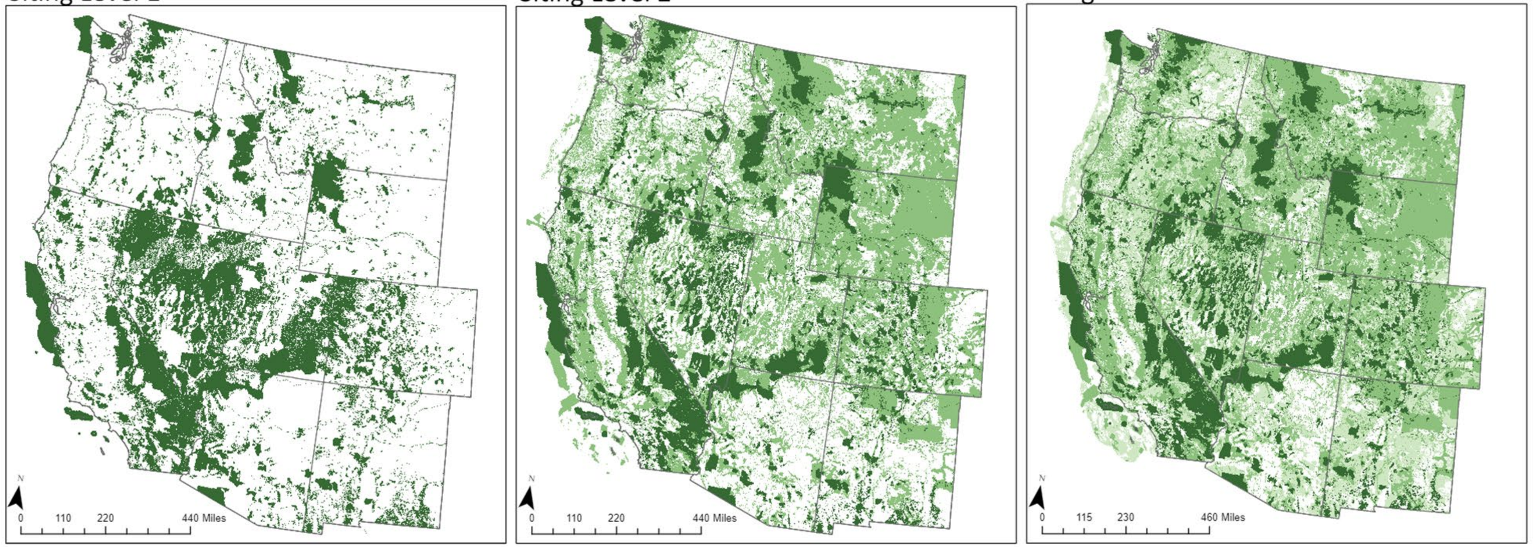
- Land use considerations are an input to the model through screening at a disaggregated level of where infrastructure projects could be located
- Every scenario complies with most restrictive land use constraints in The Nature Conservancy's *Power of Place-West* study: legally protected, administratively protected, and high conservation value lands (Levels 1 – 3)

Siting Level 1 | Siting Level 2 | Siting Level 3



Excludes Category 1 | Excludes Category 1, 2 | Excludes Category 1, 2, 3

Wind and Solar Account for Largest Incremental Land Use Footprint

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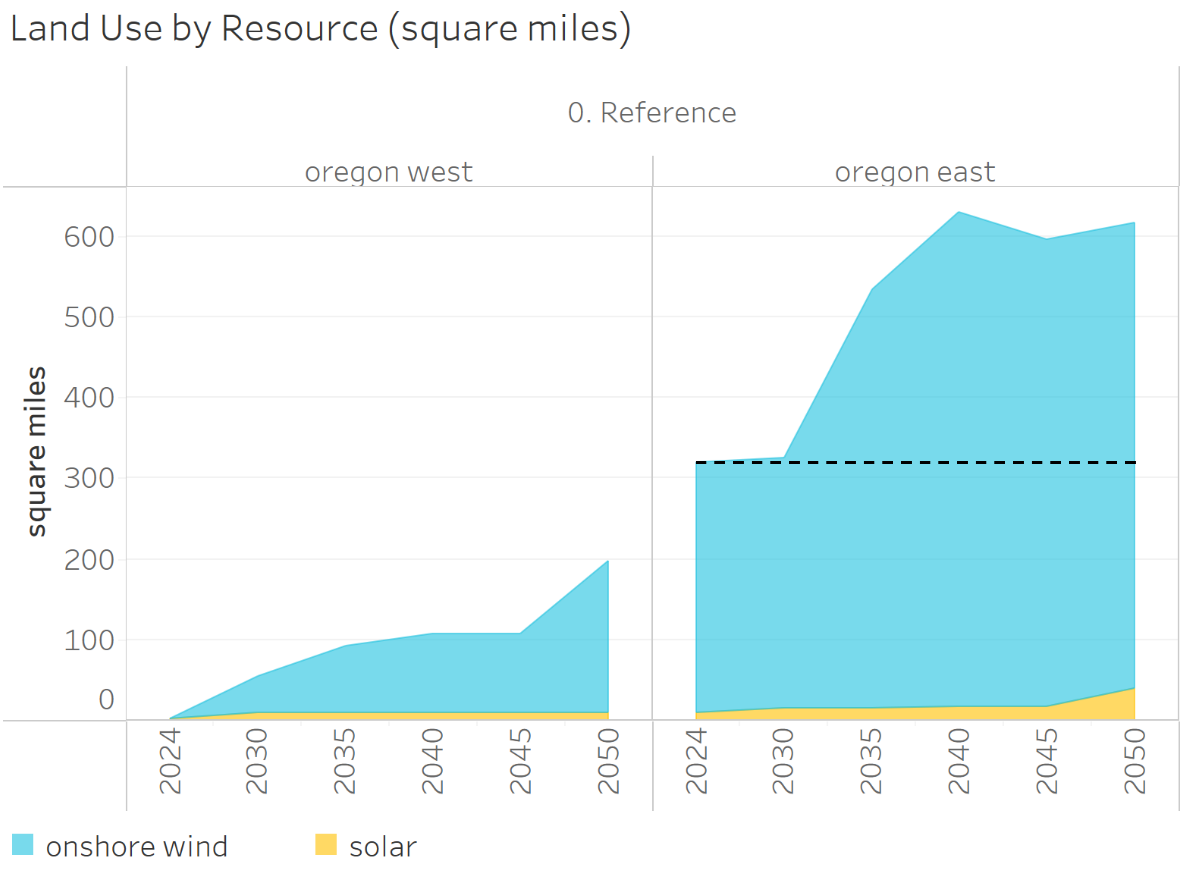
- Reference finds 620 square miles of development in OR East and 200 square miles in Oregon West by 2050
- Scenarios affect scale of land use and natural resource footprint
  - 31% reduction when limit development
  - 15% increase when take out clean gas as a reliability resource
- Other resources will have a footprint but wind and solar are the largest contributors



We use NREL estimates of wind and solar land use. Wind: 78 square miles/GW. Solar: 7 square miles/GW

Oregon Needs More Transmission Capacity

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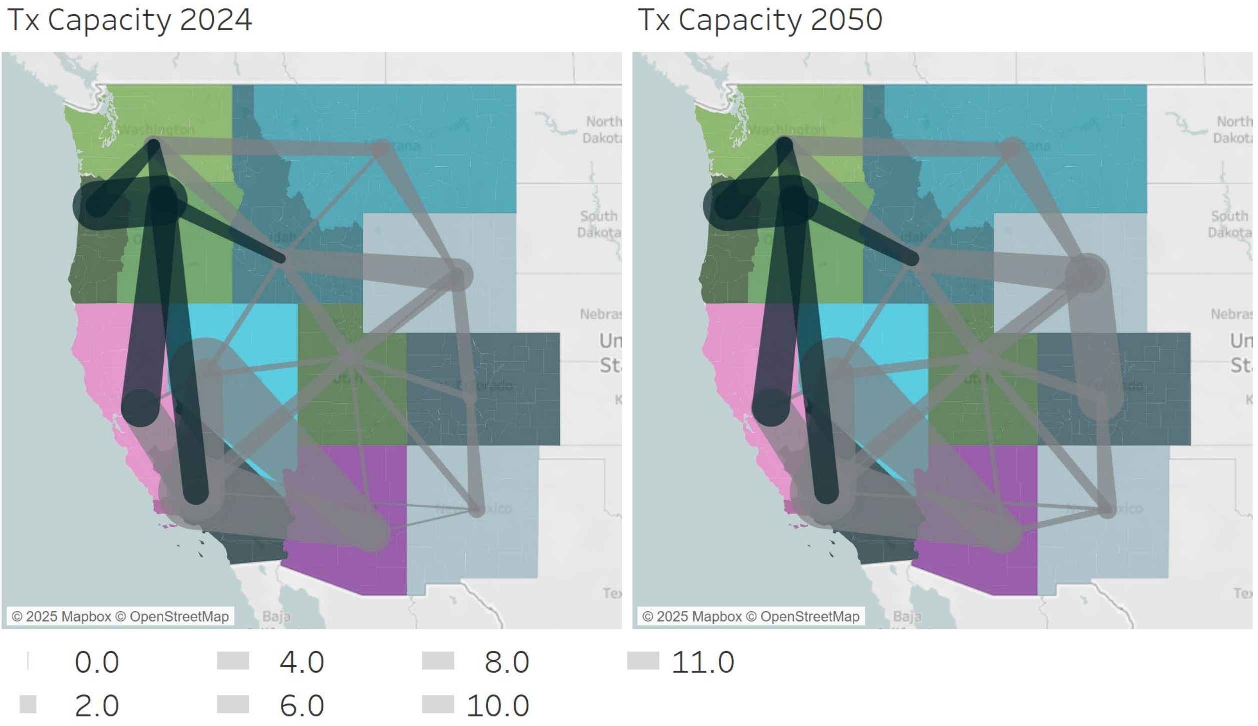
- Transmission expansion focuses between zones:
  - Across the Cascades, and from Oregon to Idaho, Washington, and California
- The transmission model is linear, so investments can be made in fractions of new transmission lines
- These results are indicative of transmission need but do not replace detailed transmission planning
- Growth of transmission into Oregon West and Boardman to Hemingway transmission project into Oregon East
- If less clean gas capacity built in Oregon West or demand response is limited, more transmission is needed



Oregon Needs More Transmission Capacity

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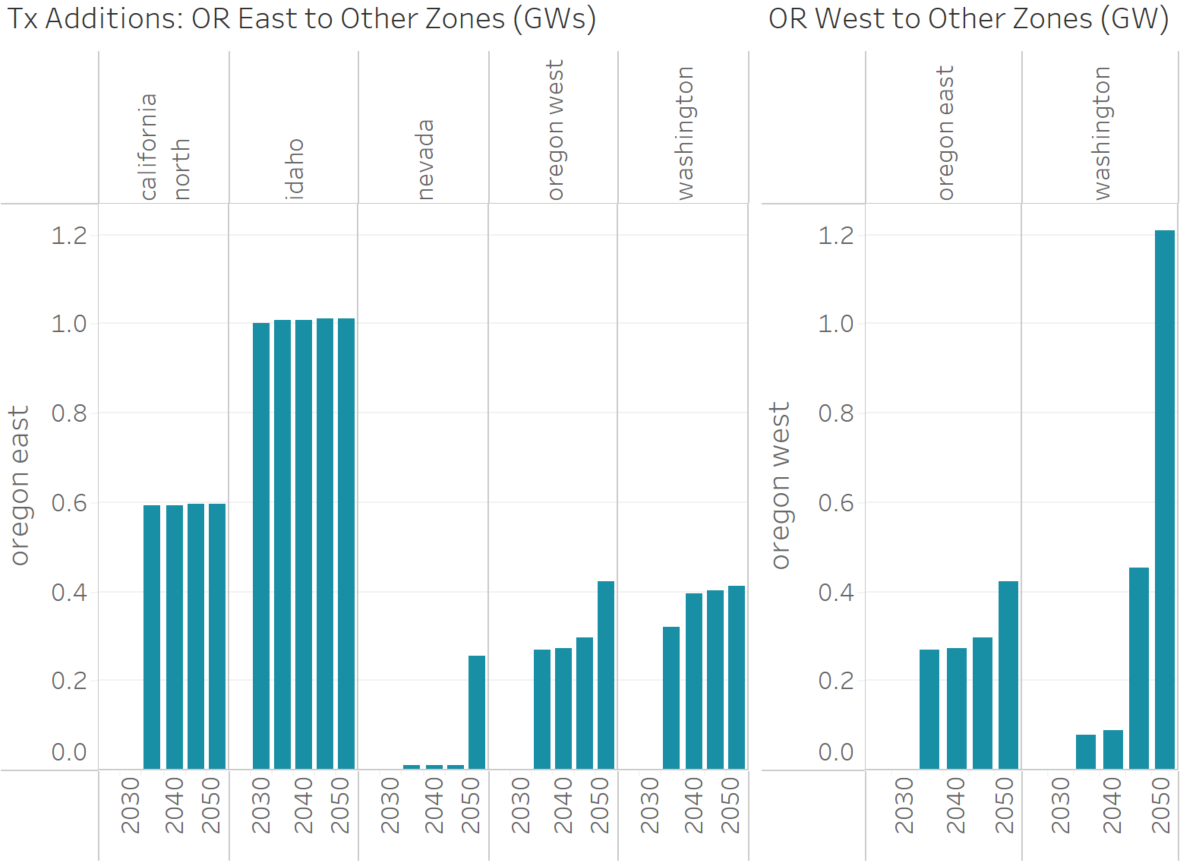
- Transmission expansion between Oregon zones and other zones is not permitted in the modeling until 2035 to represent the long lead time of transmission projects
  - The exceptions are Boardman to Hemingway, which comes online as planned in 2030
- Transmission expansion facilitates imports of renewables from other regions as well as Oregon East-West electricity flows
- The transmission model is linear, so investments can be made in fractions of new transmission lines
- These results are indicative of transmission need but do not replace detailed transmission planning



Within Zone Transmission

- No physical representation of within zone transmission or distribution
  - High-level approach to estimating electric and gas T&D costs
  - Correlates in-state electric transmission and distribution capacity expansion costs with the total increase in net distribution system peak
- Captured with historical transmission and distribution costs
  - Uses historical $/MWh from EIA
- Model optimization decisions are not impacted by electric T&D cost assumptions; flexible load is a notable exception
  - Higher distribution upgrade cost assumptions will drive more load shifting in the model; lower costs will drive less load shifting

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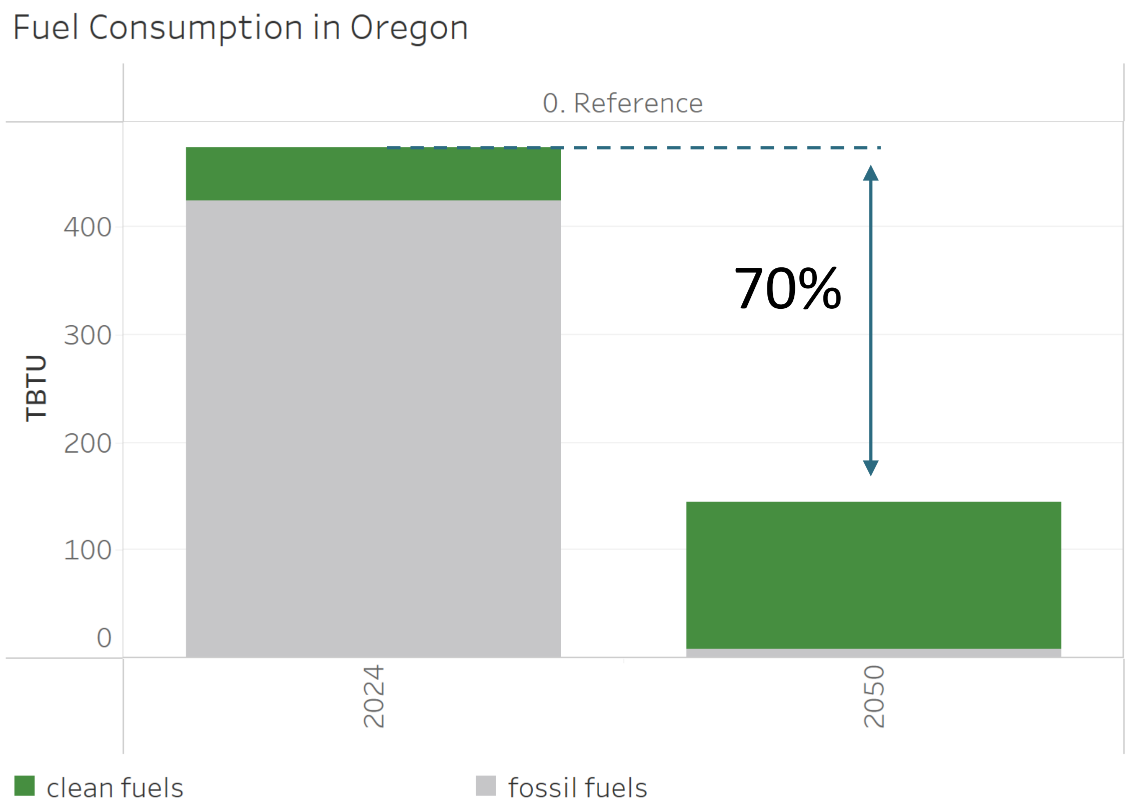
Fuels Sector Insights

Clean Fuels are Needed to Meet Energy and Emissions Goals

- Fuel demands decrease over time but their importance does not
  - Hardest to decarbonize sectors
  - Resilience
  - Time for electric technologies to replace fossil
- Clean fuels include biogas, bio liquids, e-fuels, hydrogen, ammonia, and geothermal steam



Cost comparison of fuels on $/MMBTU basis

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- Ranges of fuel costs from the literature:

1. Natural gas: $3-$5/MMBTU
2. Gasoline and Diesel: $15-$25/MMBTU
3. Electrolytic Hydrogen: $6-$12/MMBTU forecast (https://www.spglobal.com/commodity-insights/en/news-research/latest-news/coal/033020-green-hydrogen-costs-can-hit-2kg-benchmark-by-2030-bnef). Currently $30-$50/MMBTU
4. Anerobic digestion gas: $2-$18/MMBTU (https://www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth/sustainable-supply-potential-and-costs)
5. Advanced biofuels: $16-$42/MMBTU https://task39.ieabioenergy.com/wp-content/uploads/sites/37/2020/02/Advanced-Biofuels-Potential-for-Cost-Reduction-Final-Draft.pdf

Fuels in Transportation Decrease due to More Efficient Electric Drivetrains and Convert to Clean

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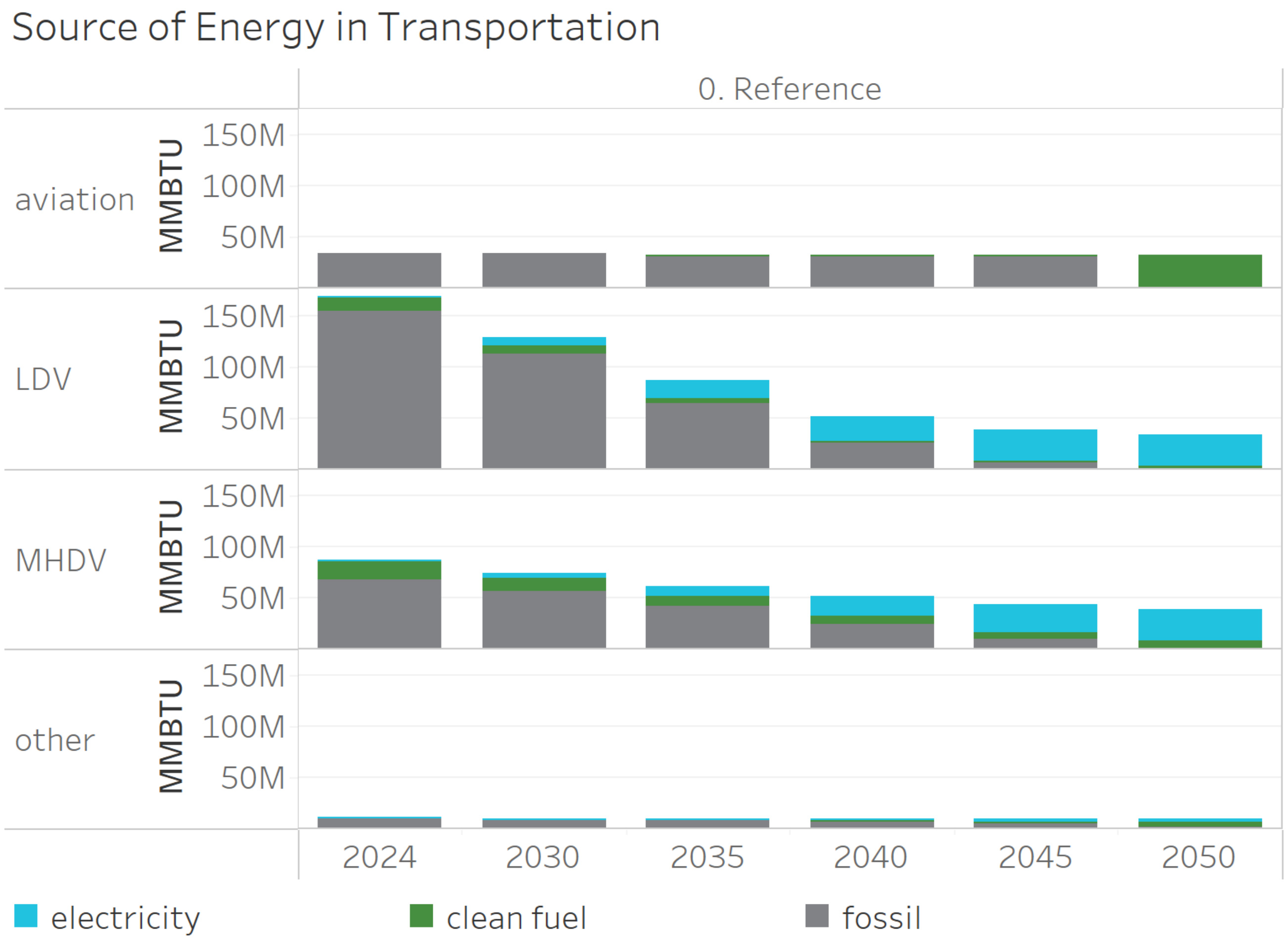
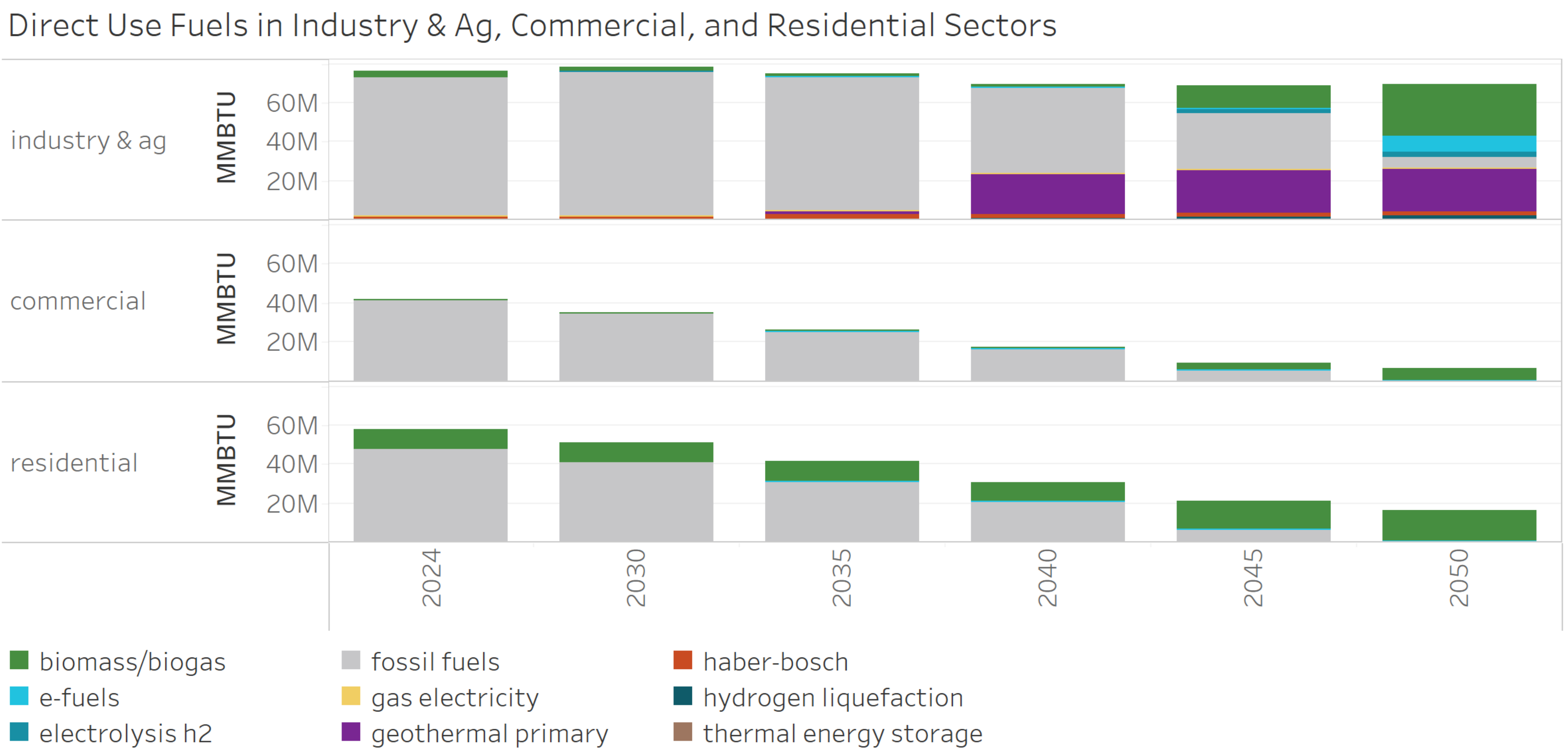
- Electrification of light duty and medium duty vehicles
- Dependent on clean fuels
  - Aviation
  - Medium and Heavy-Duty Vehicles
  - Freight rail
  - Maritime



Direct Use Fuels Support Industrial Production and Mostly Phase Out in Buildings



The Electricity System Relies on Installed Gas Capacity to Provide Flexibility and Reliability

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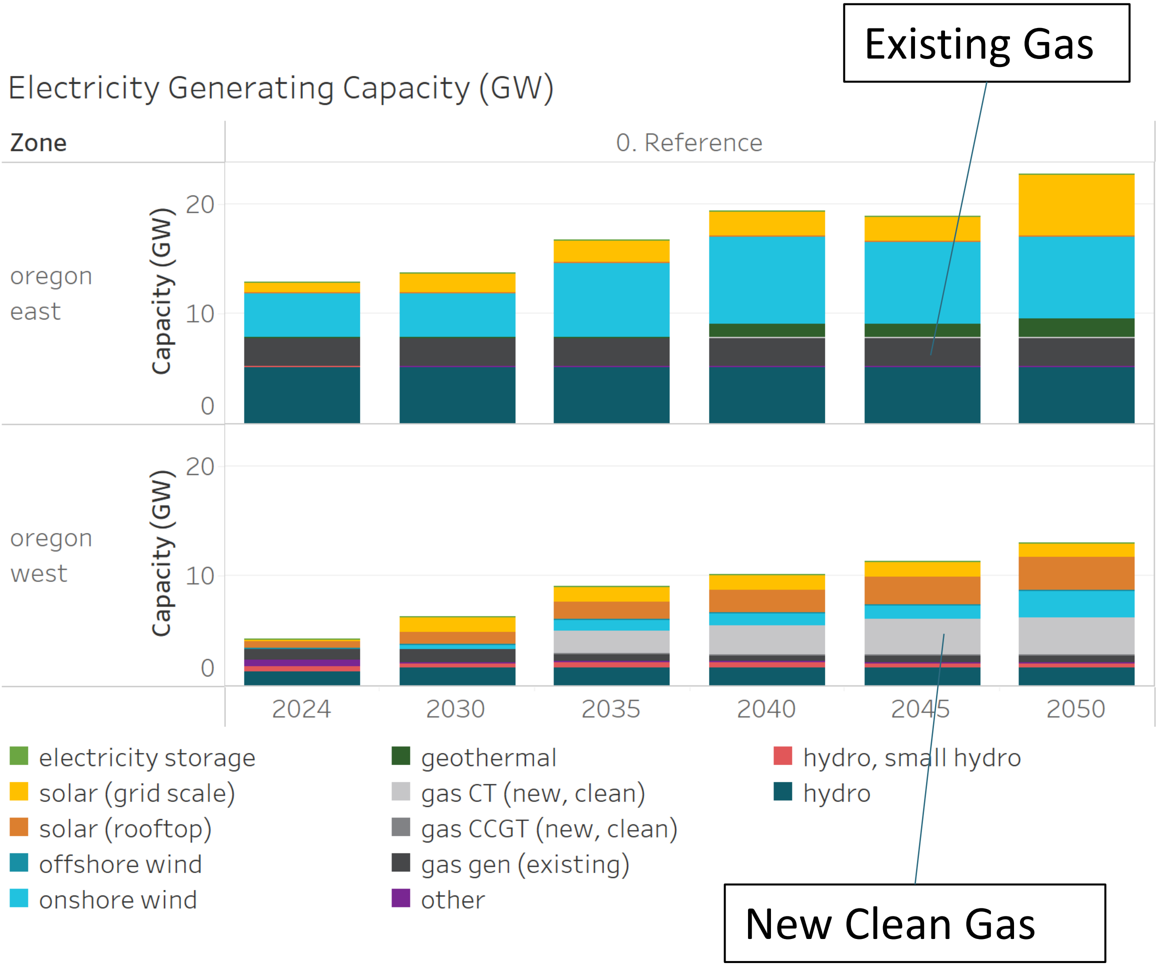
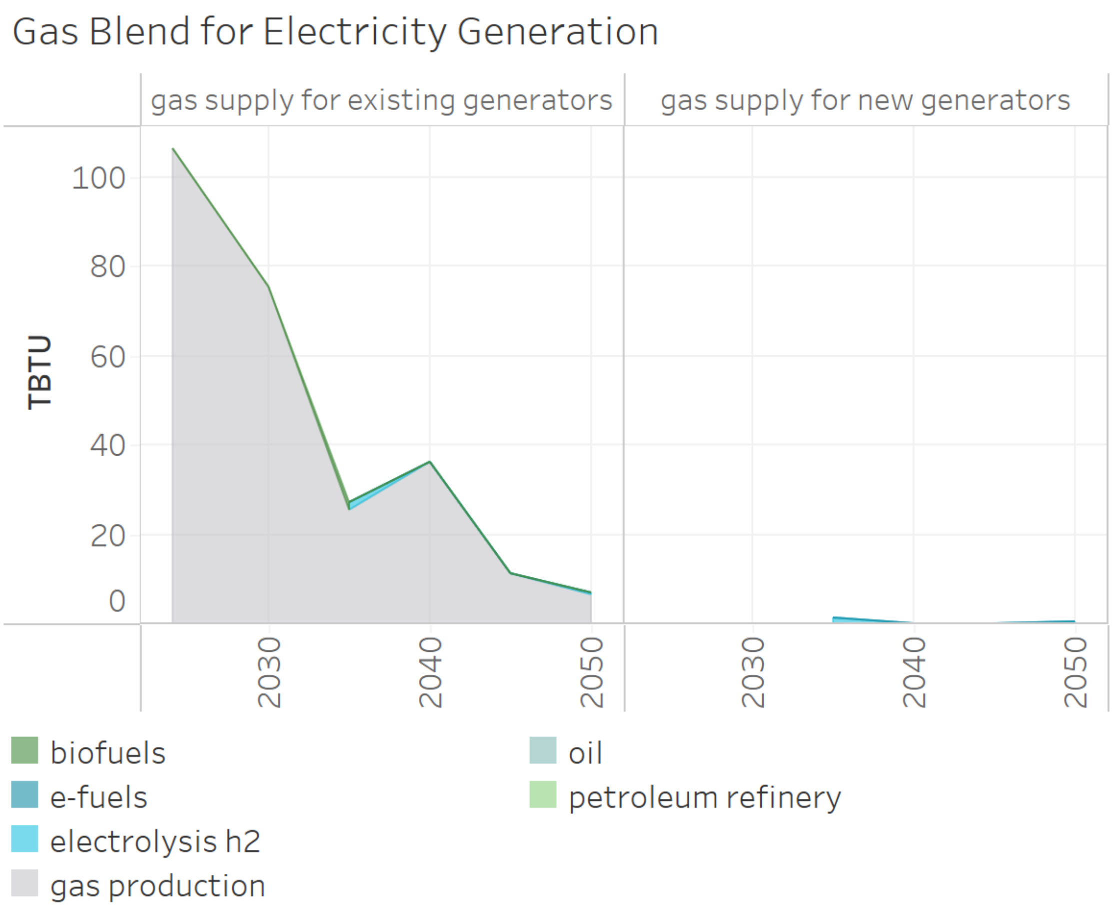
- Flexible capacity is needed to makes sure the system stays reliable
- New clean gas resources can only burn hydrogen or new sources of biogas
- New clean gas resources almost never operate
  - Expensive fuel but cheap capacity



Gas Generators Use Very Little Fuel in the Future

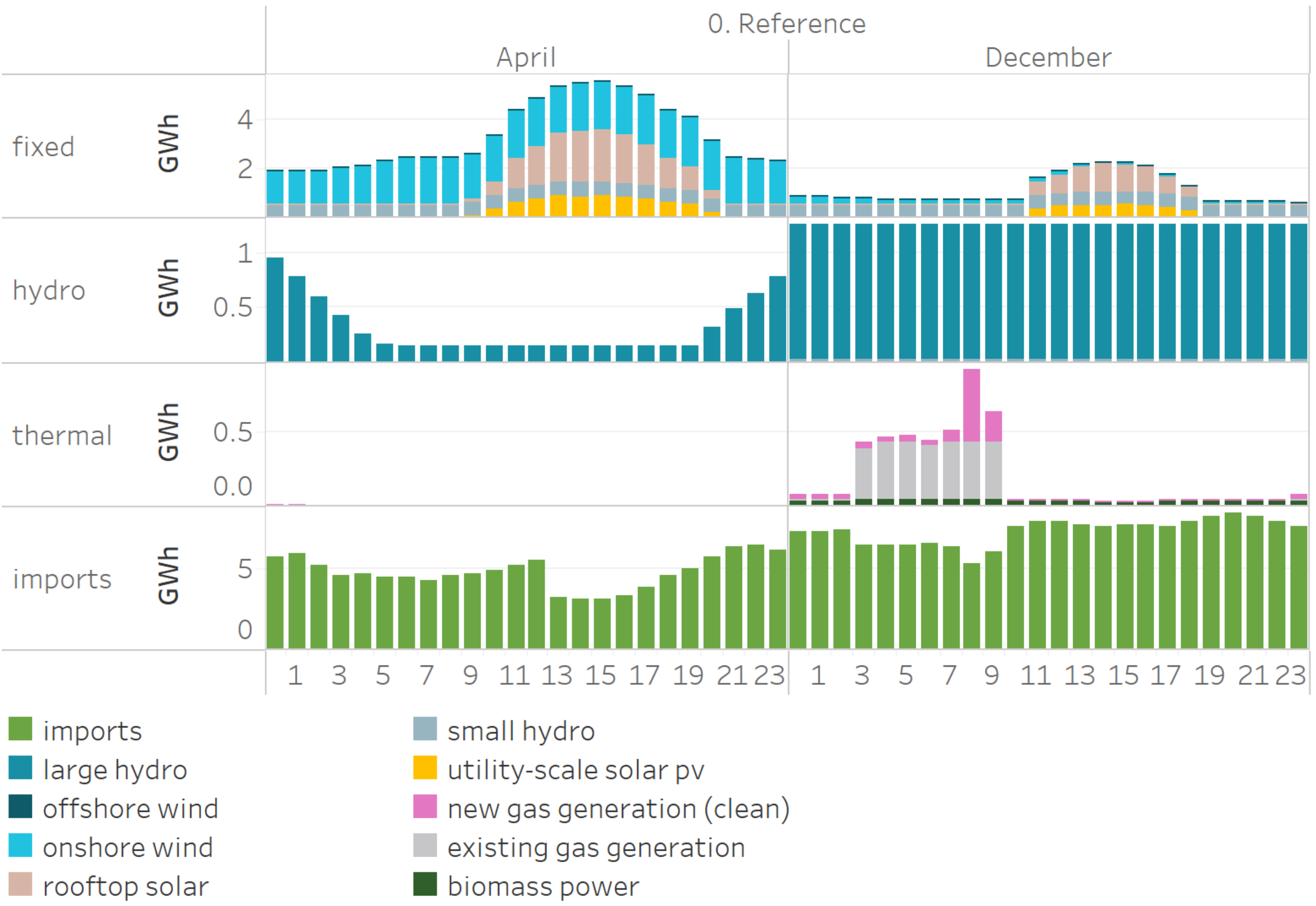
- High value flexibility role on the system
- Providing capacity during periods of low renewable output/high loads/low hydro conditions requires low volumes of fuel
- New clean gas resources use the most expensive fuel so use the lowest fuel volumes



Example Hourly Operations in 2050 in Oregon West

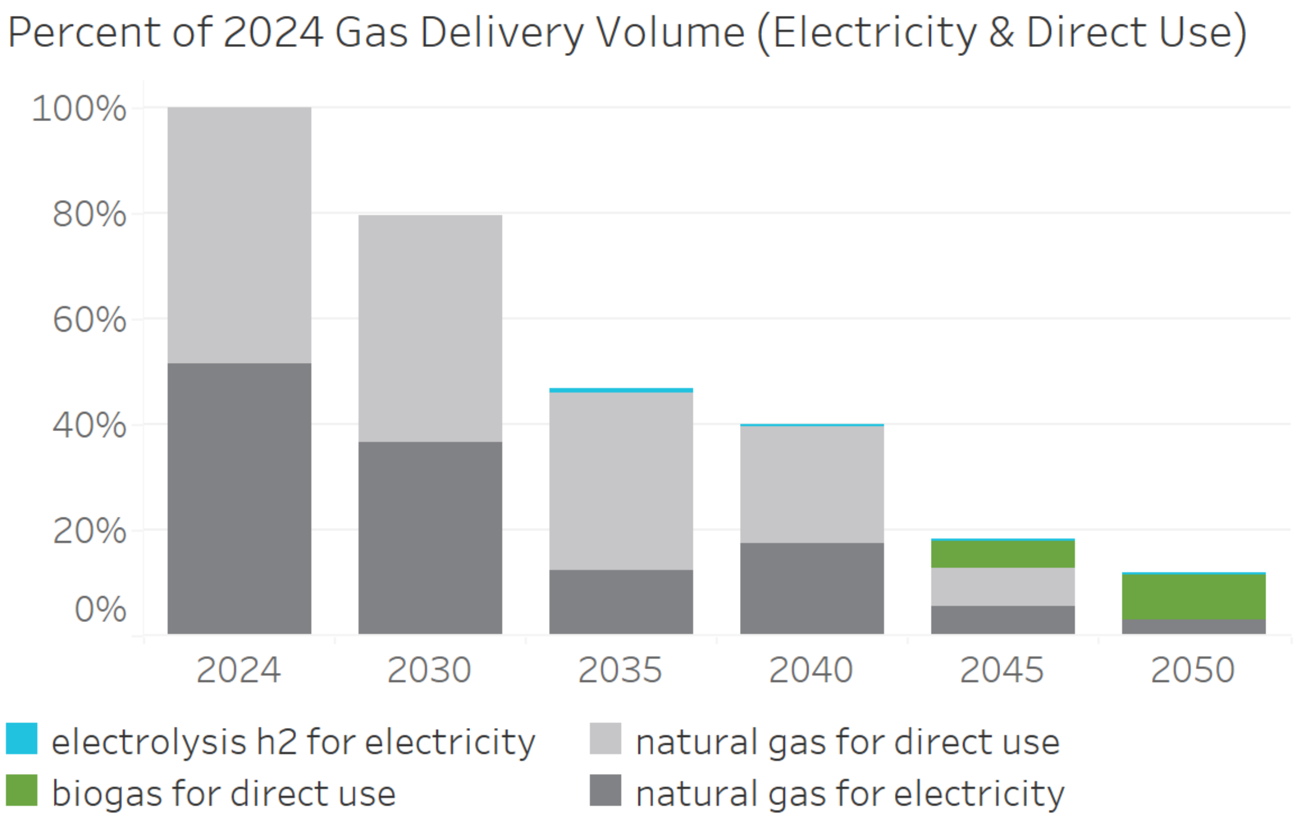
- The December day shows limited renewable availability, and the April day shows renewable energy abundance
- Lack of wind in the December day drives need for hydro, imports, and gas, including new gas generation using electrolyzed hydrogen
  - New clean gas capacity is used infrequently, providing power during conditions where loads are hard to meet
- High renewable availability drives down hydro dispatch and imports, and gas generation is effectively zero on the April day with abundant renewables

High Renewable and Low Renewable Example Days in 2050



Volumes of Gas Delivered to Electricity Generators and End Users Declines Over Time

- Gas volumes decline over time with reductions in MWh of generation from gas turbines and electrification of end uses
- Small amounts of electrolytic hydrogen used in power generation in new clean gas turbines
- Remaining volumes of direct use gas fully decarbonized with biogas



Biofuels are Important to Decarbonize the Low Volumes of Remaining Fuel Use in 2050

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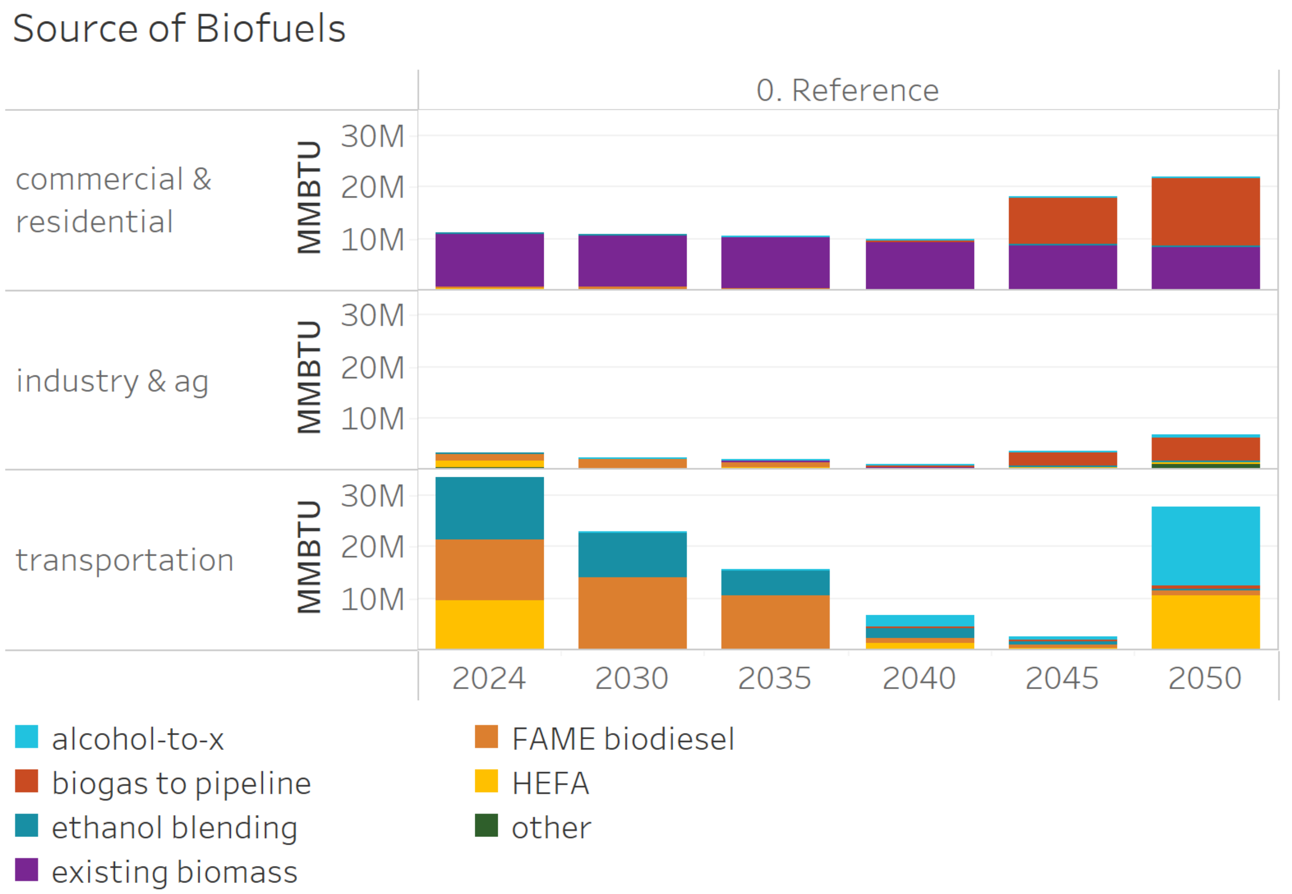
- Biofuels in 2024 consist of wood burned in residences and biofuels in transportation, including HEFA, FAME, and ethanol
- Volumes in transportation decrease as the fleet is electrified and emissions from fossil fuels decrease, but increase in 2050 to decarbonize remaining fuel use
- Other sectors consume biogas in 2045 and 2050 to remove emissions from remaining gas use



Liquid E-Fuels are Imported from Other States whereas Hydrogen Gas is Produced Locally

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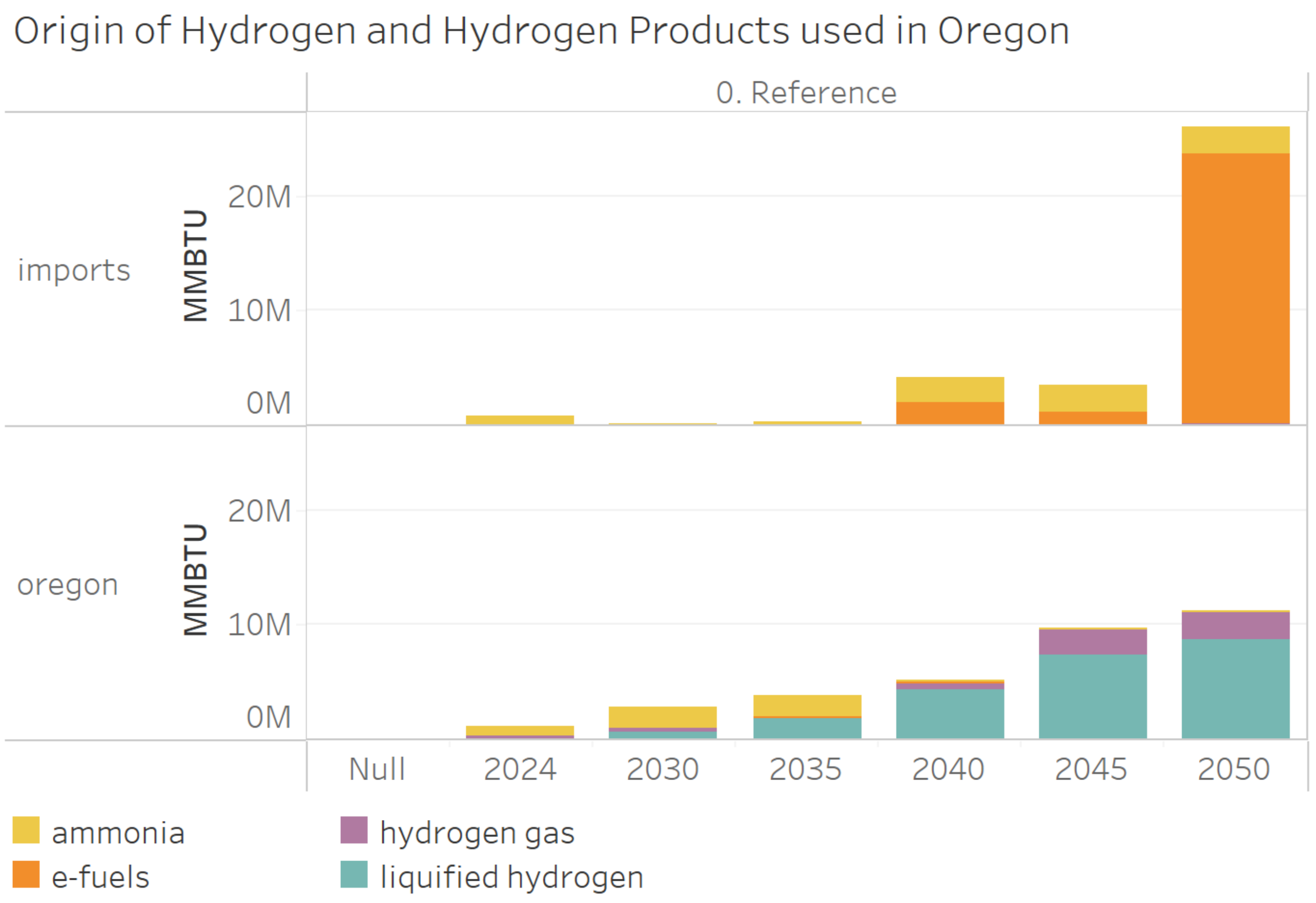
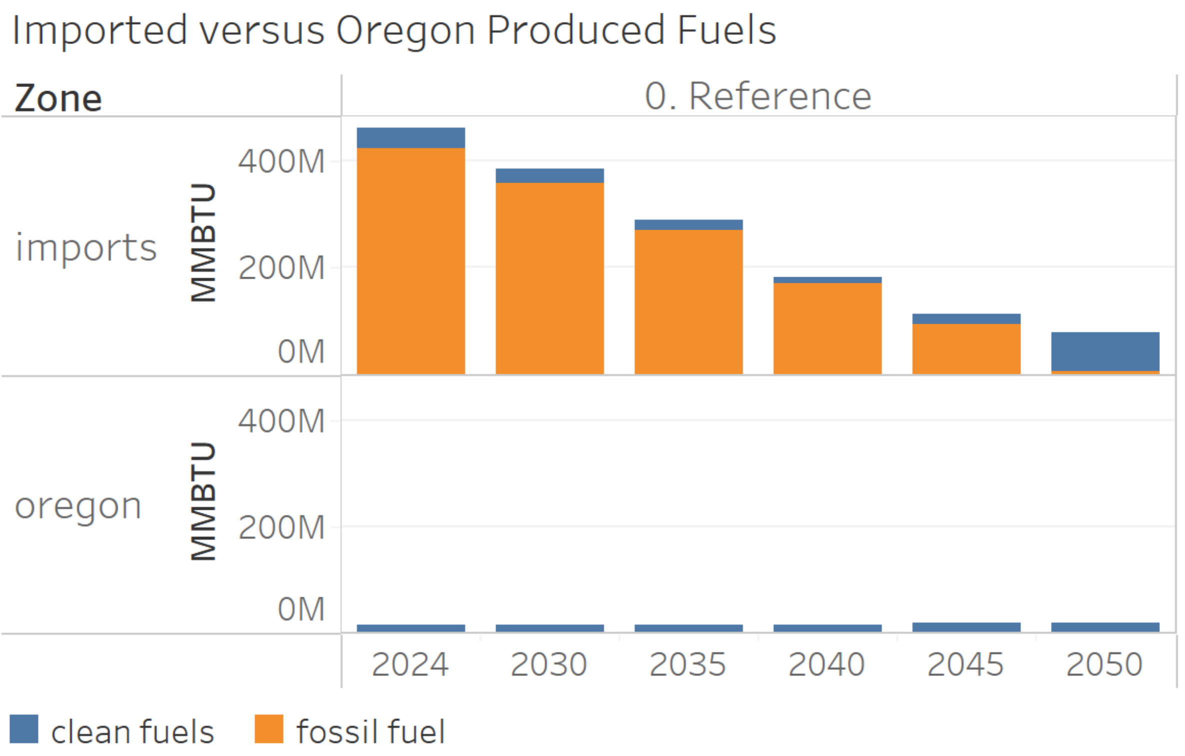
- Hydrogen products consumed in Oregon shown on the previous slide are sources from inside and outside of Oregon
- Liquid fuels are cheap to import, and e-fuel liquids are imported from other states
- Liquified hydrogen and hydrogen gas are produced within Oregon and ammonia production is split between in-state and out-of-state production



Fuels: Imported vs. Produced in OR in Reference and Alternative Scenarios

- Fossil fuels are sourced entirely from out of state, relying on larger oil and gas markets, and out-of-state refining
- Fuel imports decline as fuel use declines
- The majority of clean fuels are sourced out of state
- In-state clean fuel growth from direct use of electrolysis H2 and hydrogen liquefaction



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Transportation Sector Insights

Transportation Key Findings

- Transportation electrification plays significant role in reducing system-wide energy demand across all scenarios, despite tech sector growth.
- Early adoption of electric vehicles, including MHDVs, reduces the costs of decarbonization.
- EVs are a significant driver of increased electric loads but can provide a net benefit to the grid if managed flexibly.
- Reducing VMT per capita provides significant value but will require investment.
- Low carbon fuels play a strategic role in decarbonizing transportation and this role increases as pace of TE slows.

Impact on Economy-wide Energy Demand

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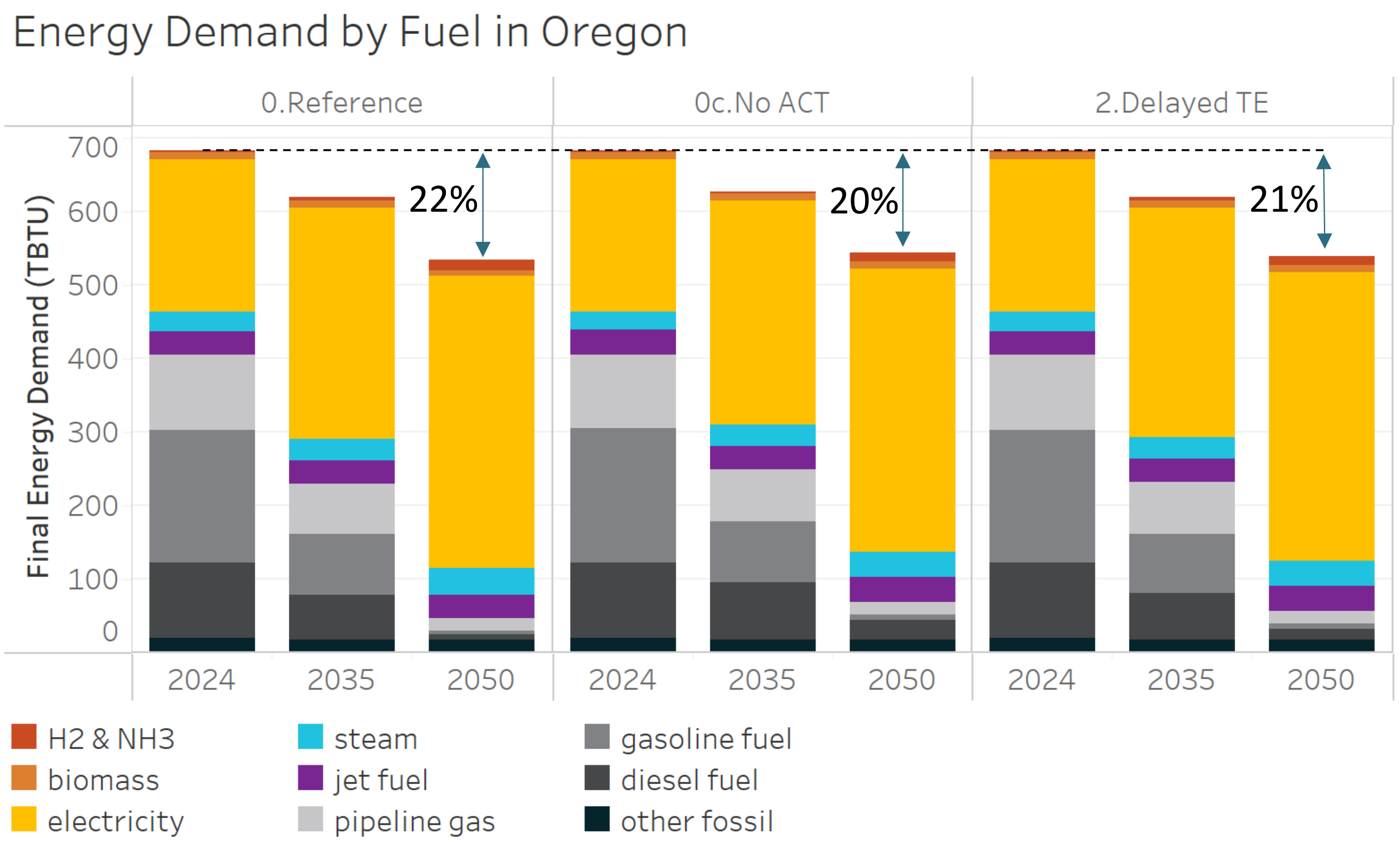
- Overall energy demands are impacted by the level of MHDV electrification
- More significant is the impact on fuel use
  - No ACT: Diesel consumption is 25% higher in 2035 and 270% higher in 2050 than in the Reference Scenario
  - Delayed TE: Diesel consumption is 110% higher in 2050 than in the Reference Scenario
- Additional fuel use increases the volume of clean fuel needed in the long term



Costs: TE Scenarios Difference to Reference

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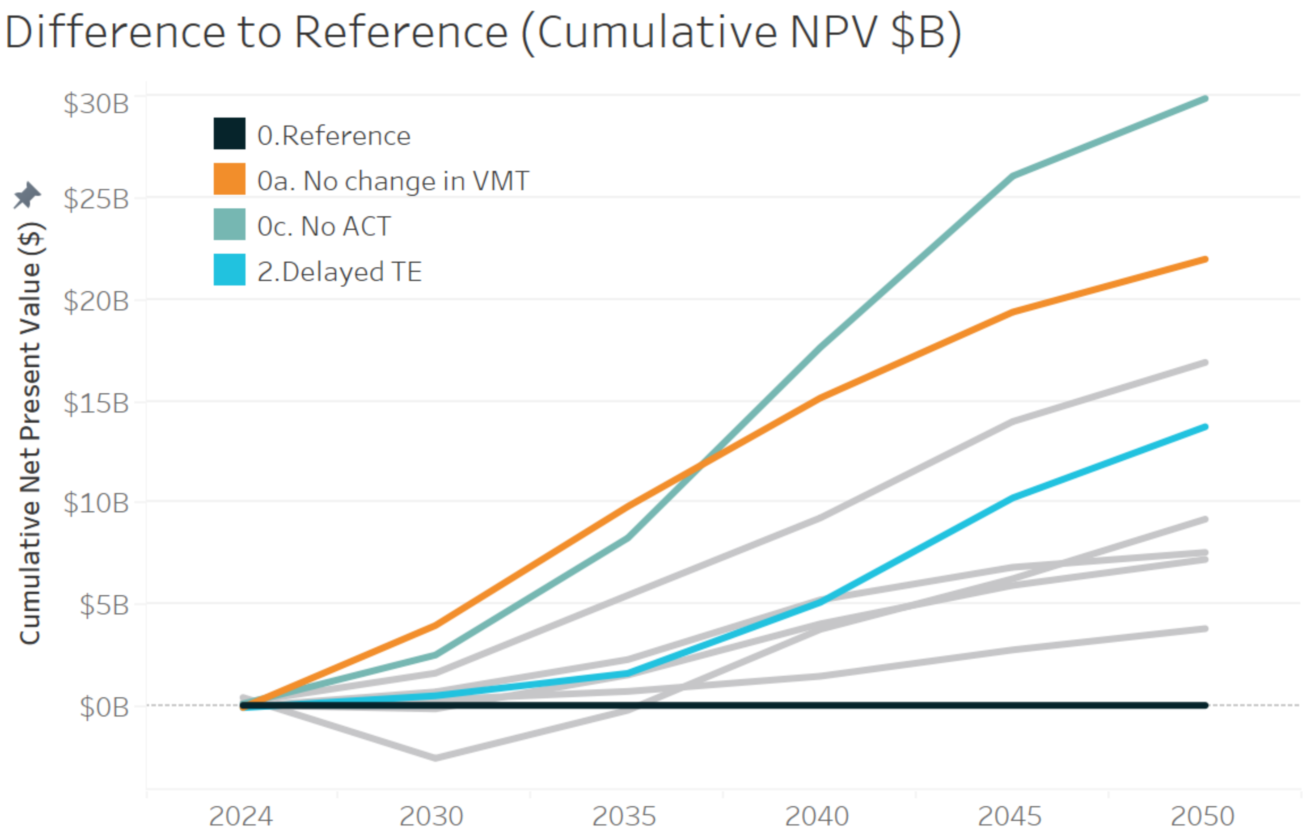
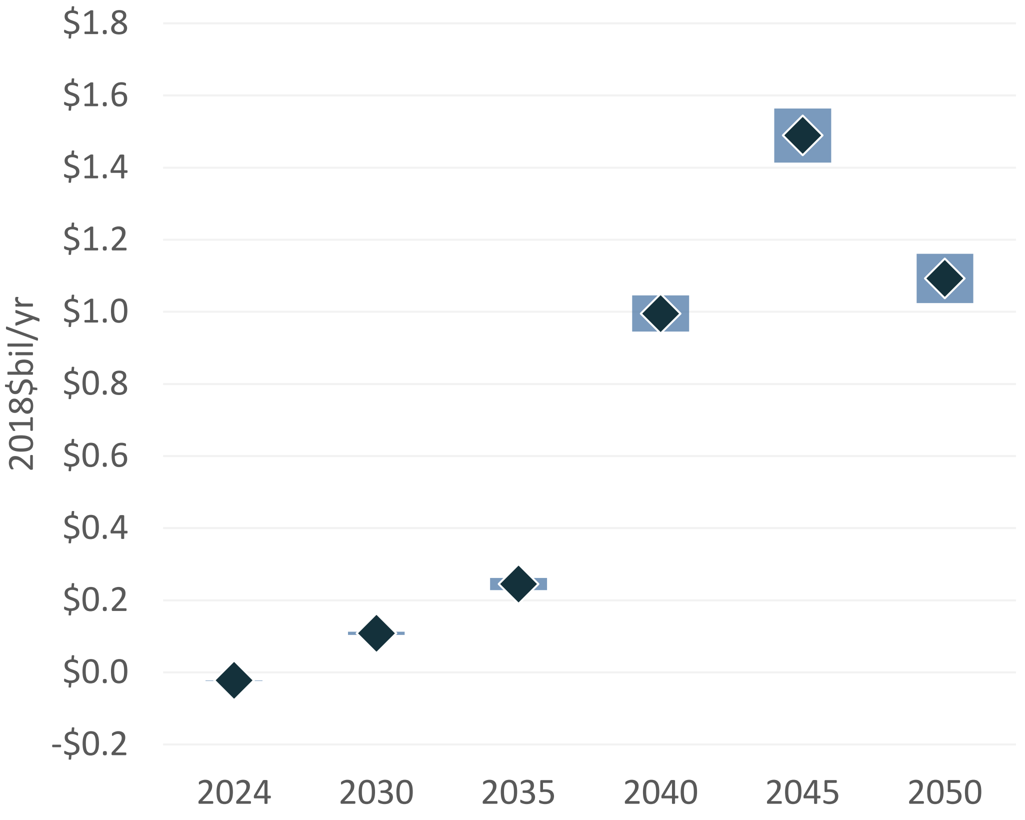
- Delaying when Oregon reaches 100% medium- and heavy-duty ZEV sales by 10 years increases costs
  - Puts more pressure on clean fuels to meet targets
- Oregon's goal of 20% VMT reductions save $22B NPV over 25 years
- No ACT is $16B NPV higher over 25 years than Delayed TE
  - Shows stock rollover of MHDVs in the 2030s is important for cost containment



Electrification Remains Cost Effective with Changes in Vehicle Pricing

- Cost sensitivities of +/-10% on ZEV capital and fixed costs (including vehicle prices, fixed O&M, and installation costs) relative to Reference remain higher than Reference
- The strategy of vehicle electrification remains cost effective under vehicle cost changes

Difference in Annualized Cost between Delayed TE and Reference. Error Bars for +/-10% ZEV Cost



Reference Scenario
Light Duty Vehicle Sales, Stock, Energy

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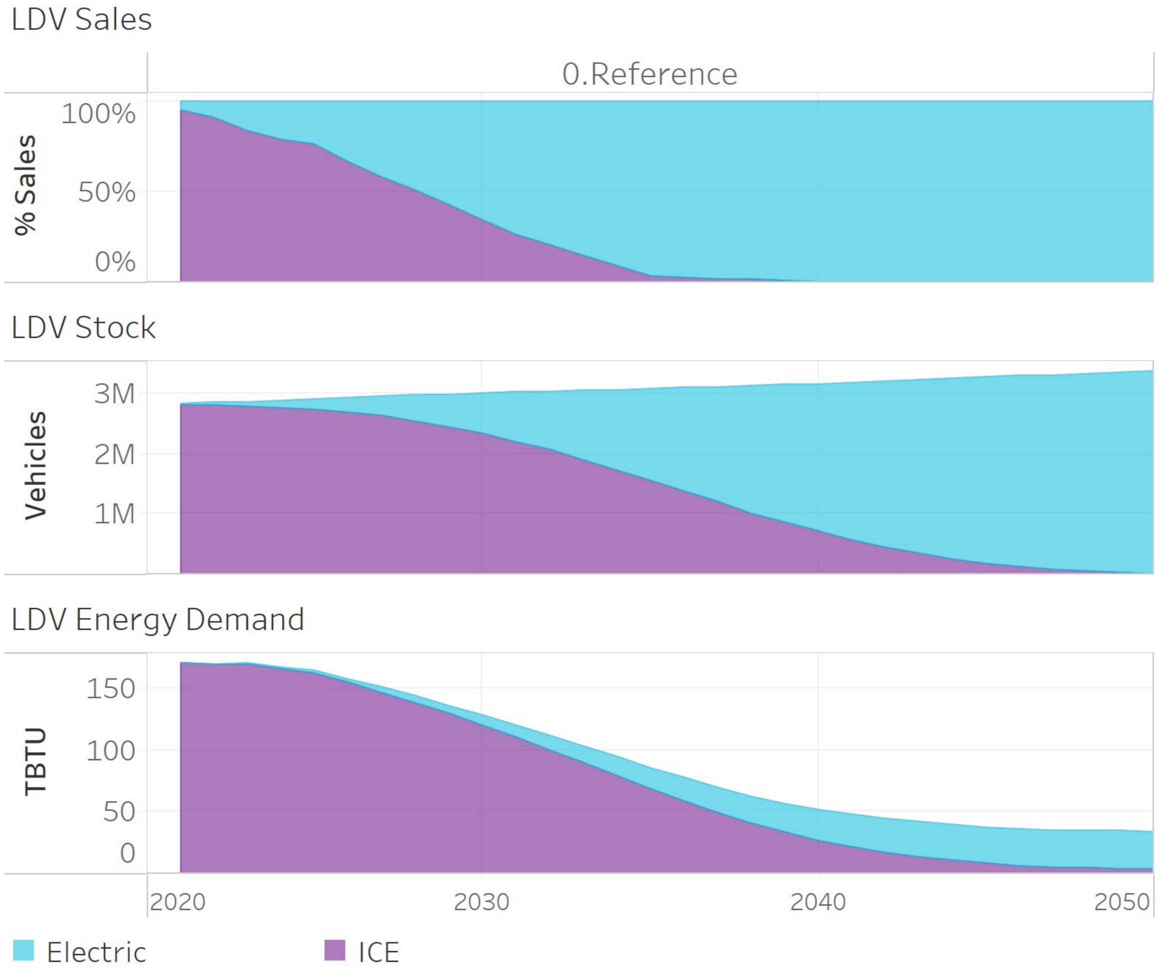
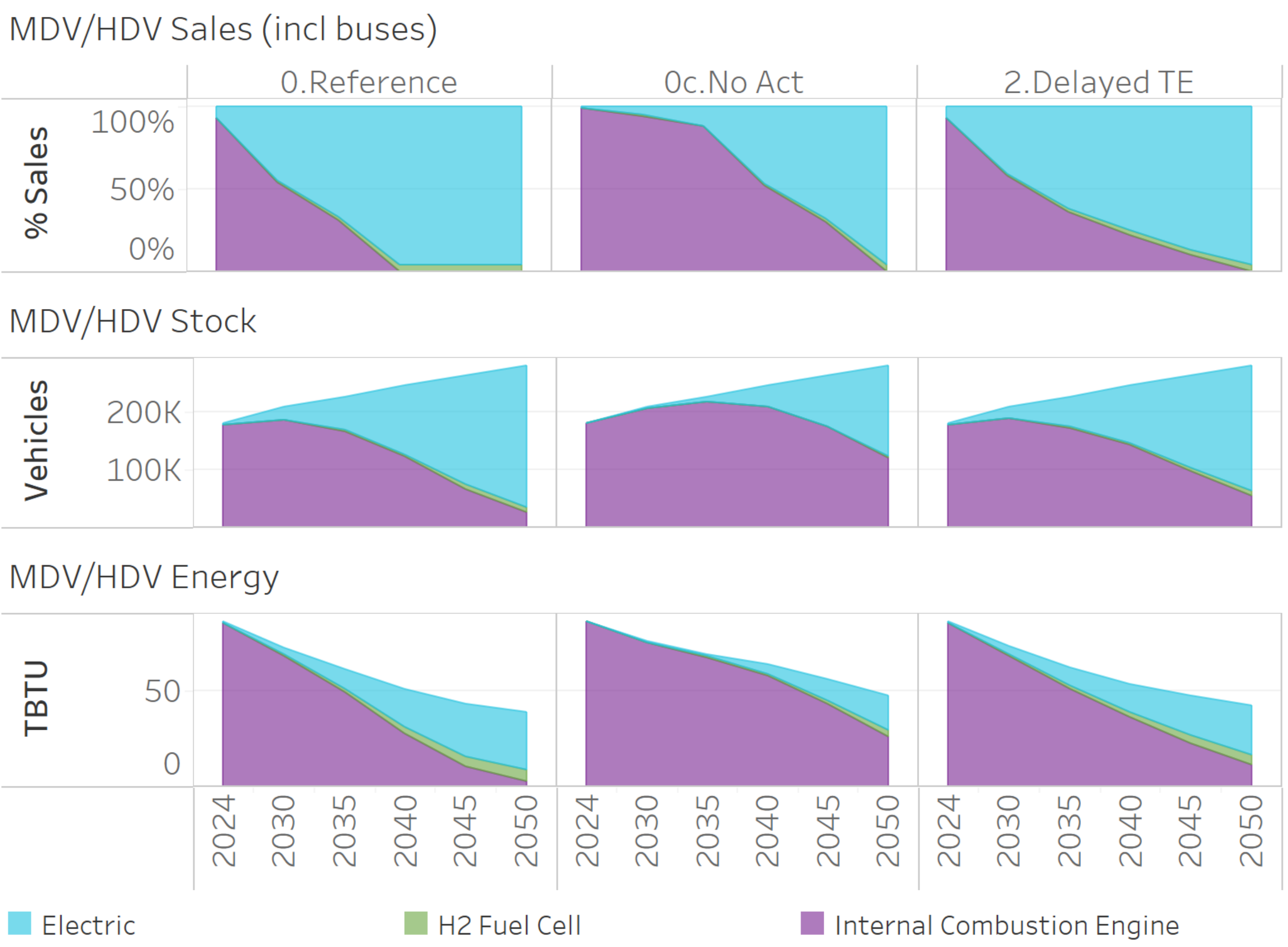
- 100% zero emissions vehicle sales achieved in 2035
- Drop in energy demand from both better drive train efficiency and 20% reduction in vehicle miles traveled by 2050



Impact of Delays on Sales, Stocks, and Energy

- Medium and heavy-duty vehicle sales are delayed in 0c. No ACT and 2. Delayed TE
  - No ACT has relatively few sales of electric vehicles through 2035, achieving 100% sales by 2050
  - Delayed TE has the same trajectory as Reference through 2035, delaying reaching 100% sales from 2040 to 2050
- The impact of the delays is to increase stocks of internal combustion engine vehicles, driving up energy demand



Electric Cars Are a Key Part of the Picture

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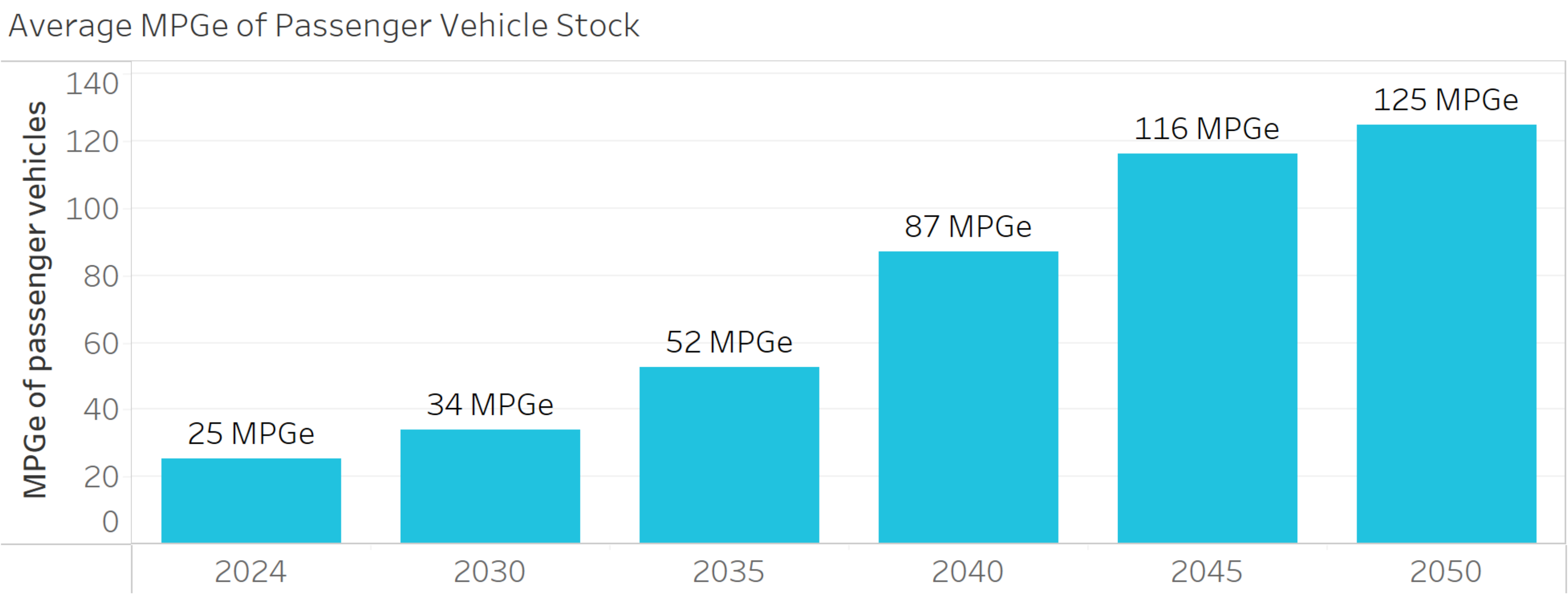

- Electric cars deliver huge efficiency gains
- Together with electrification of trucks, responsible for reducing the size of the whole energy sector by 27% over 2024 loads

Energy Reductions from Vehicle Electrification, Efficiency, and VMT Reductions Equal to 27% of Today's Energy Demand

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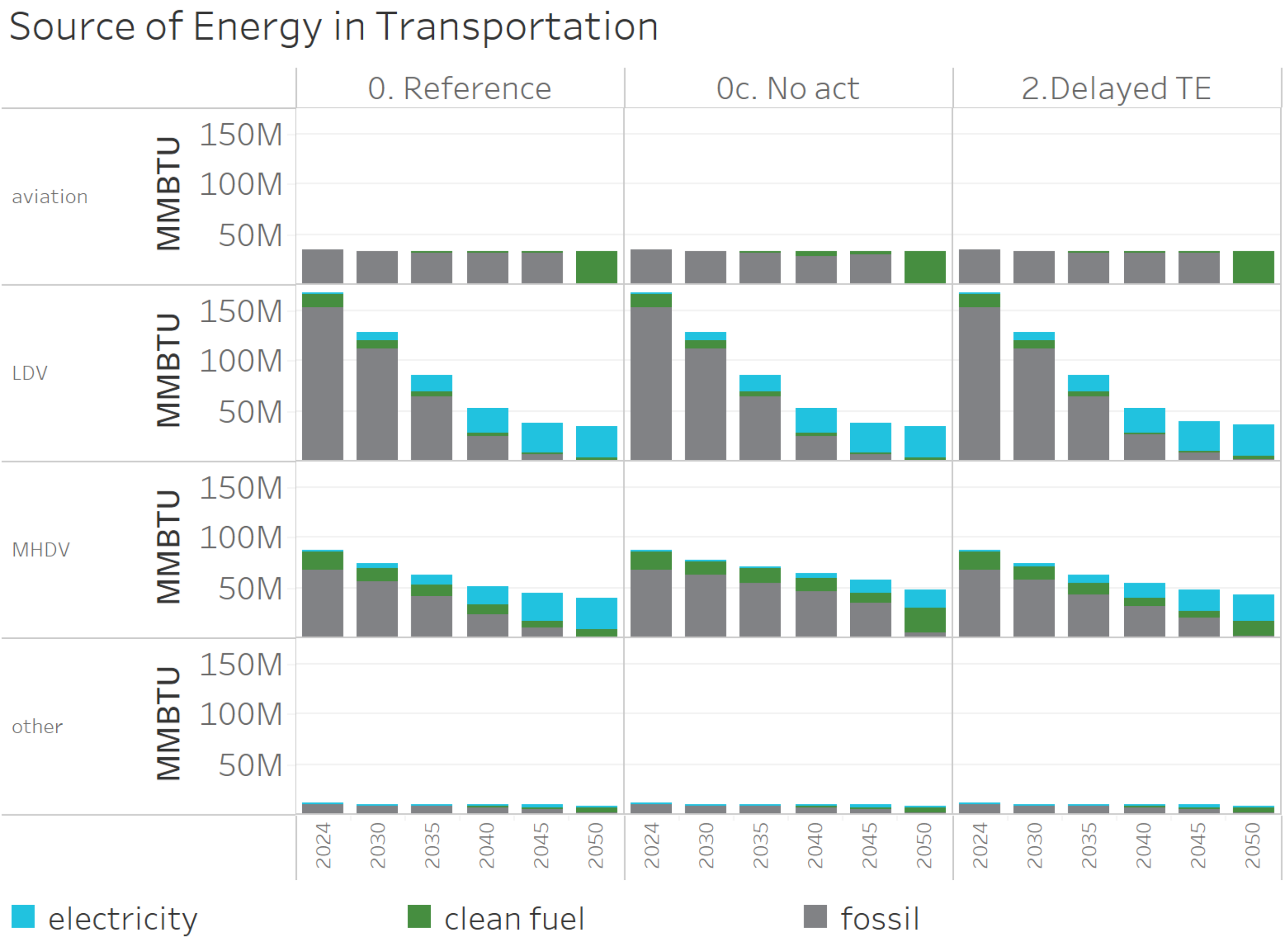
- Vehicle electrification, efficiency, and VMT reductions play an important role on reducing the overall size of the future energy system
- By 2050, the reduction is 27% of 2024 energy demands in the Reference Scenario
  - 20% of the reduction is attributable to the light duty vehicle fleet
  - 7% of the reduction is attributable to medium and heavy duty vehicles

			Percentage reduction of 2024 Final Energy Demand			
		Total Final Energy Demand (TBTU)	Total	LDV	MHDV	Other
0.Reference	2024	682.4	0.0%	0.0%	0.0%	0.0%
0.Reference	2035	618.8	15.9%	12.0%	3.6%	0.3%
0.Reference	2050	535.0	27.1%	19.6%	6.9%	0.5%

Transportation Fuel Consumption Driven by the Pace of Electrification

- The transportation scenarios investigate differences in medium and heavy-duty vehicles
  - The transition to clean energy across other subsectors is similar across scenarios
- Delays in medium and heavy-duty vehicles drives greater need for clean fuels by 2050



Flexible Loads Dependent on Customer Participation in the Future

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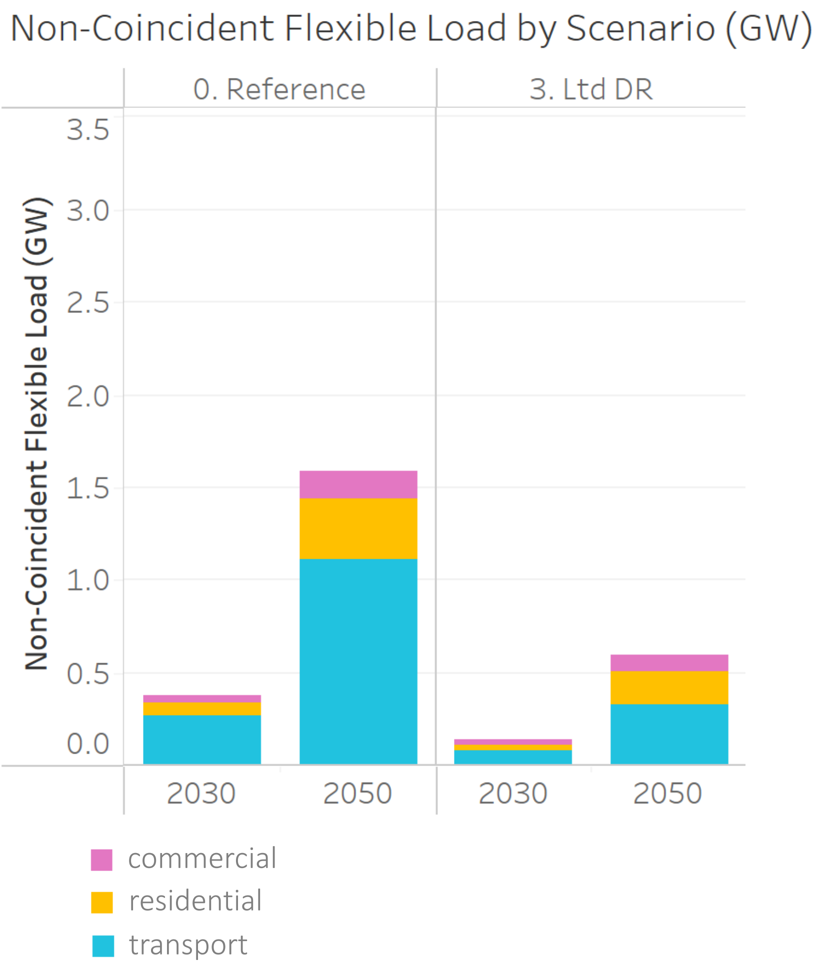
- The largest contribution to non-industrial flexible load comes from managed charging in the transportation sector
- The Reference Scenario assumes active participation of customers in demand response programs
- The capacity of flexible load contributions by 2050 will vary based on customer participation
- Limited participation costs $4B on a cumulative NPV basis over 25 years



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Buildings Sector Insights

Energy Efficiency, Building Electrification, PV, and DERs Are Important to a Least-Cost Pathway

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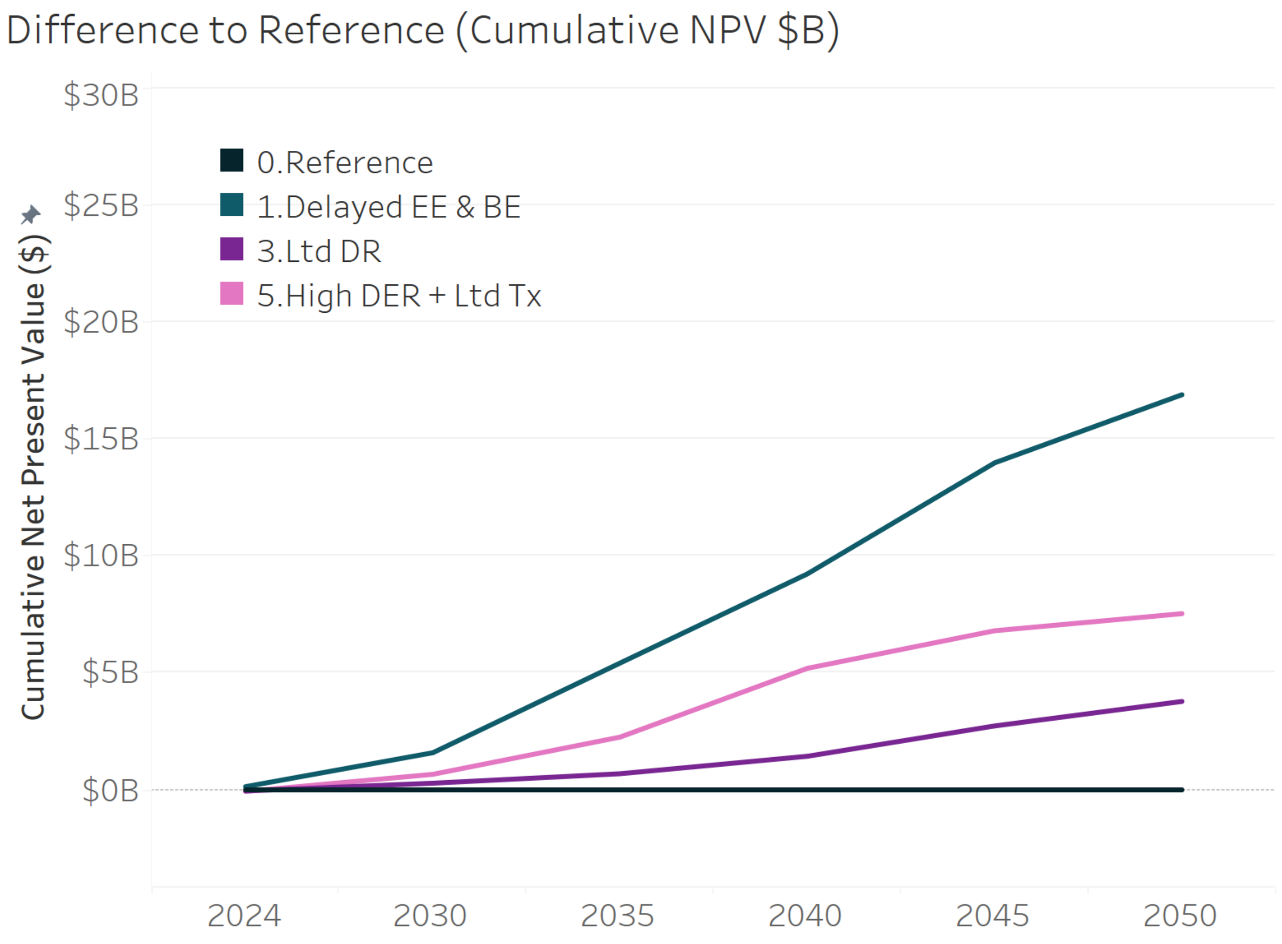
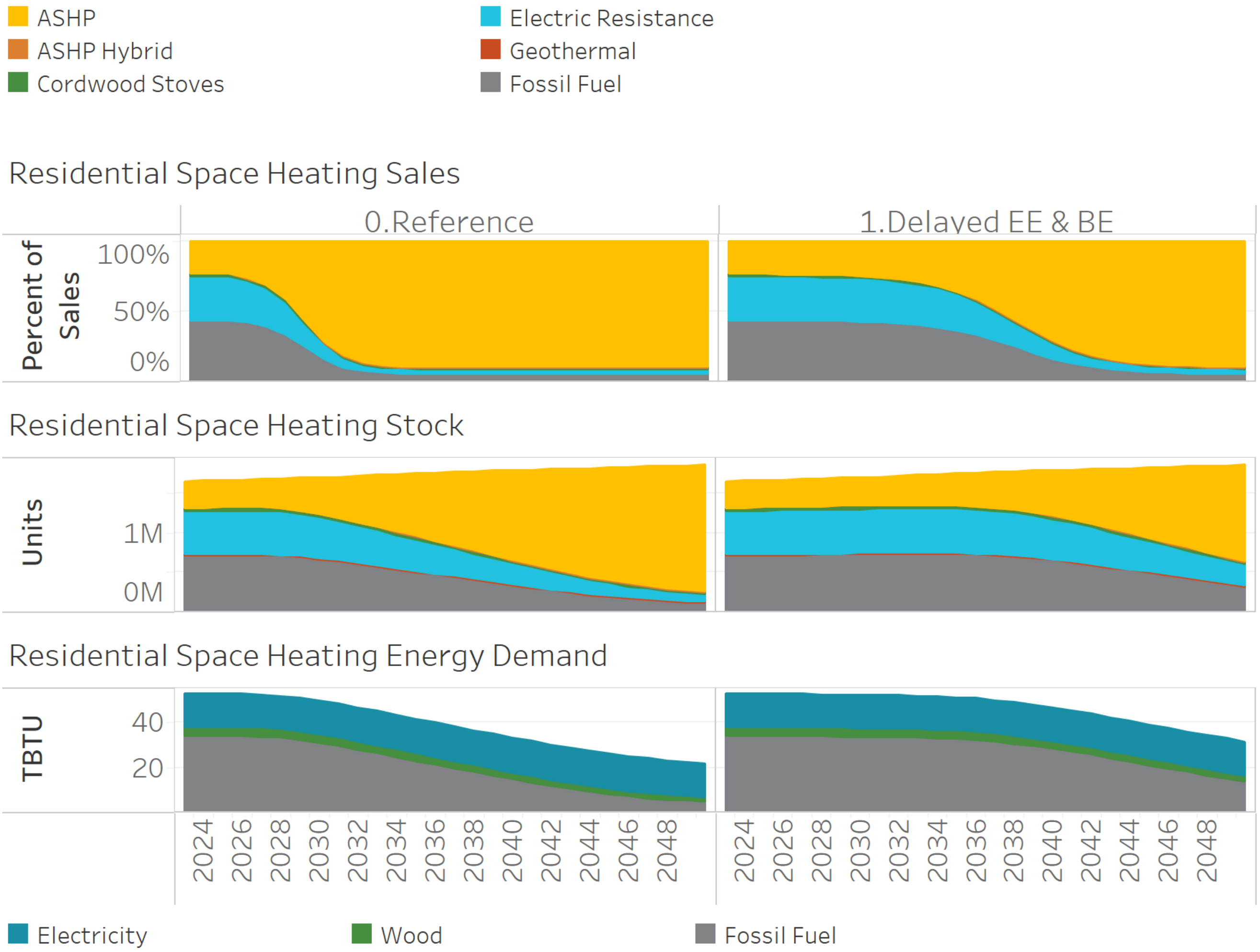
- Delaying energy efficiency and building electrification drives up costs by $17B cumulative NPV over the next 25 years, showing the importance of these measures in buildings
- The higher DER scenario increases costs by $8B cumulative NPV, but reduces the need for grid scale renewables and T&D infrastructure investment, potentially easing siting and permitting challenges
- The Limited Demand Response scenario drives up costs by $4B cumulative NPV showing the value of customer participation with new electrified end uses



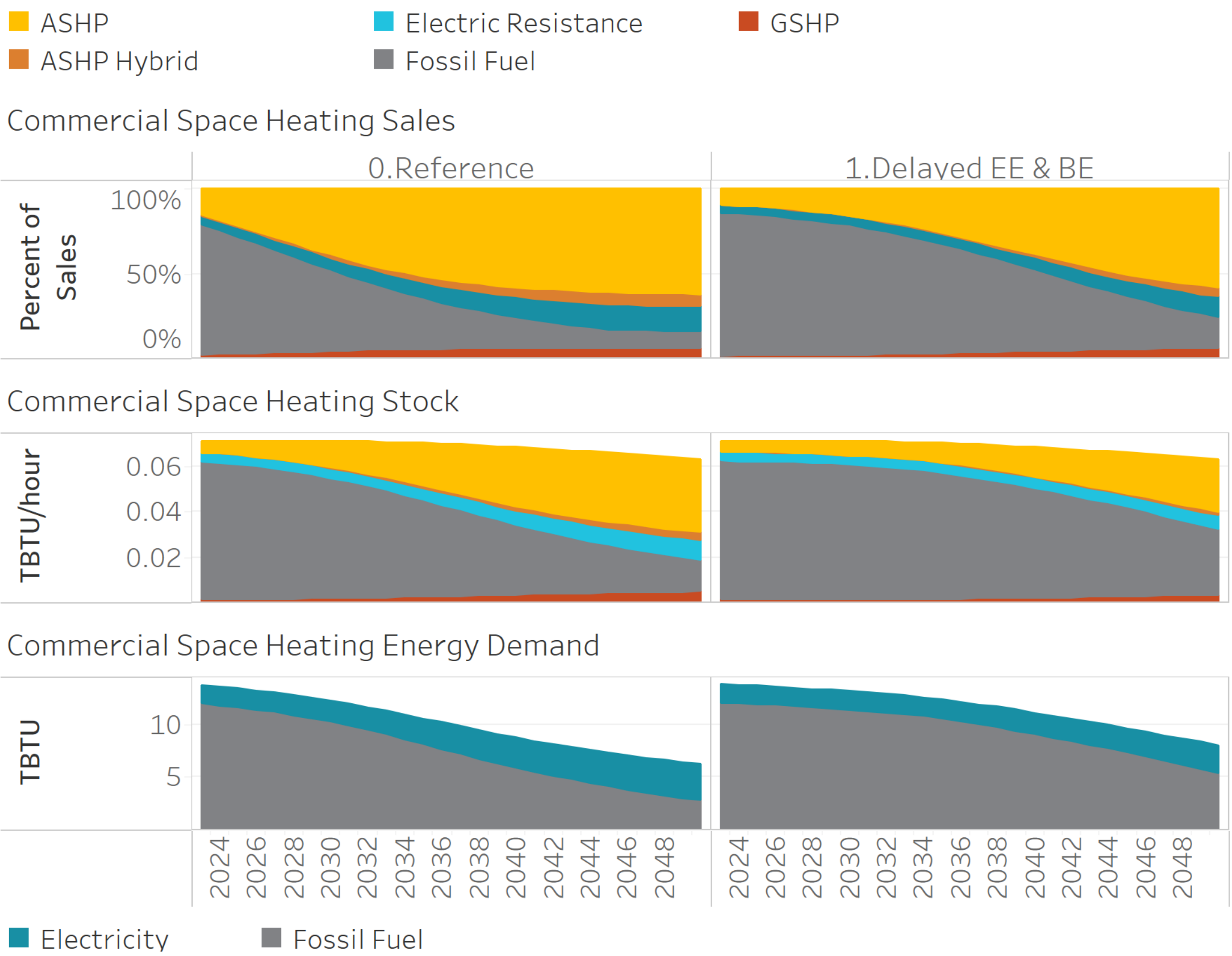
Reference Scenario
Residential Space Heating

- Fuel switching to electric heat pumps drives down overall energy demand
- 65% air-source heat pump (ASHP) sales by 2030 and 90% ASHP sales by 2040
- Wood burning stoves supplemented with hybrid systems

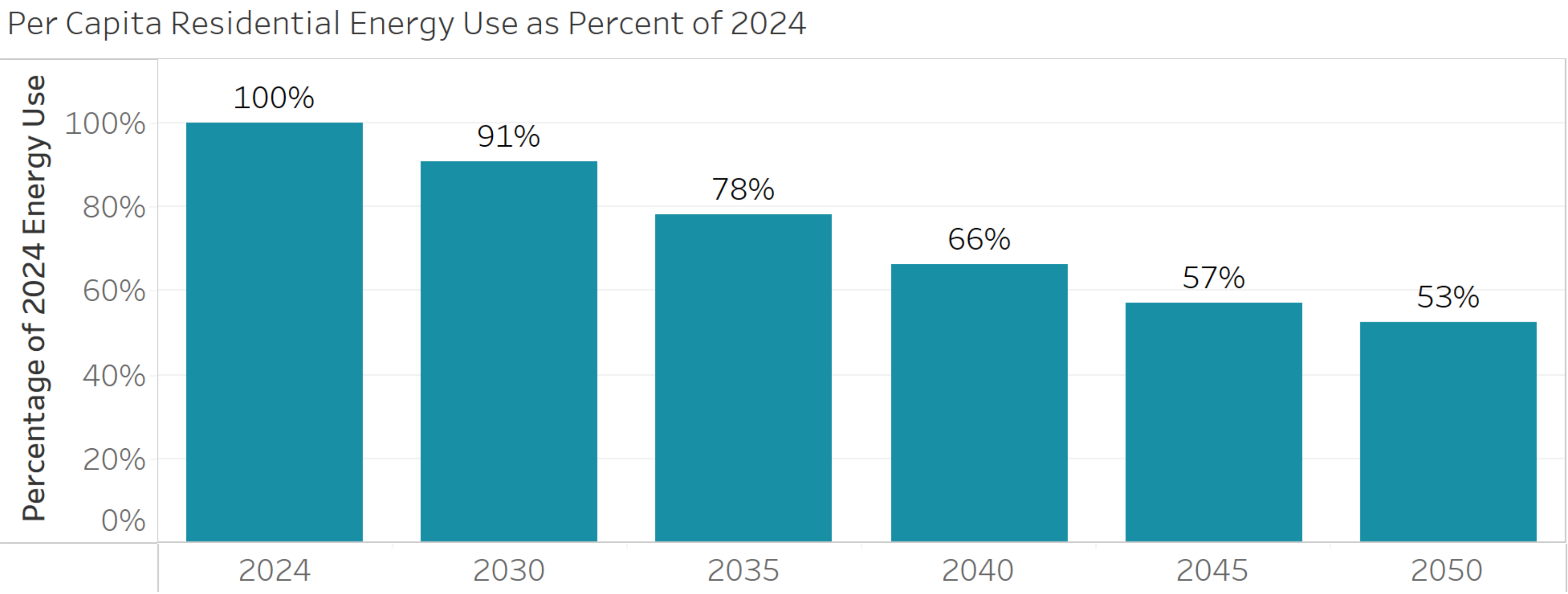


Reference Scenario
Commercial Space Heating

- Small commercial (50% of buildings) use the same assumptions as residential
- Large commercial (50% of buildings):
  - 15% ASHP, 10% electric + hybrid by 2030
  - 50% ASHP, 40% electric + hybrid by 2040
- Electricity demand doubles with 60% reduction in overall energy use by 2050



Residential Electrification and Energy Efficiency Mean a Lighter Lift to Meet Energy Demand



- Electrification of space and hot water heating are the biggest drivers of energy savings
- Other efficiency improvements from weatherization and other equipment (lighting, fridges…)
- Commercial and industrial efficiency improvements further drive down demand

Delaying Energy Efficiency and Building Electrification Increases Fuels and Electricity Use

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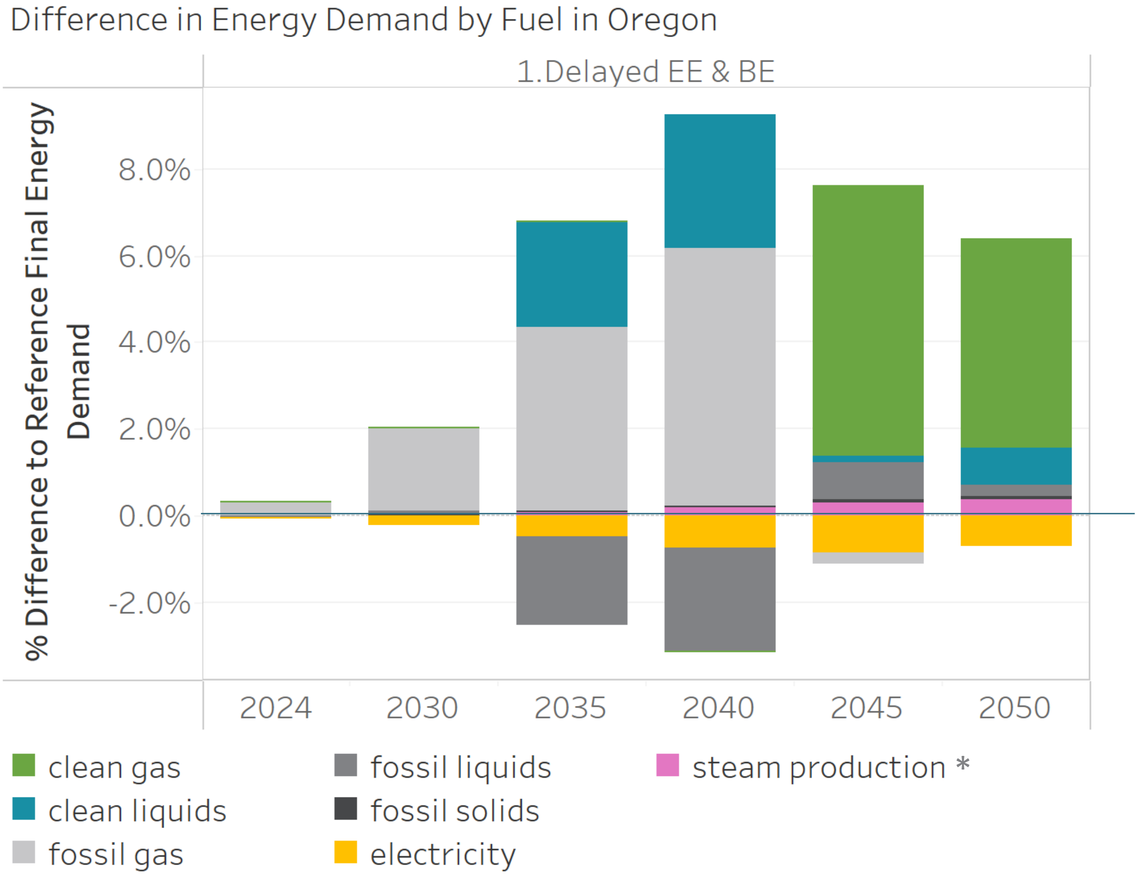
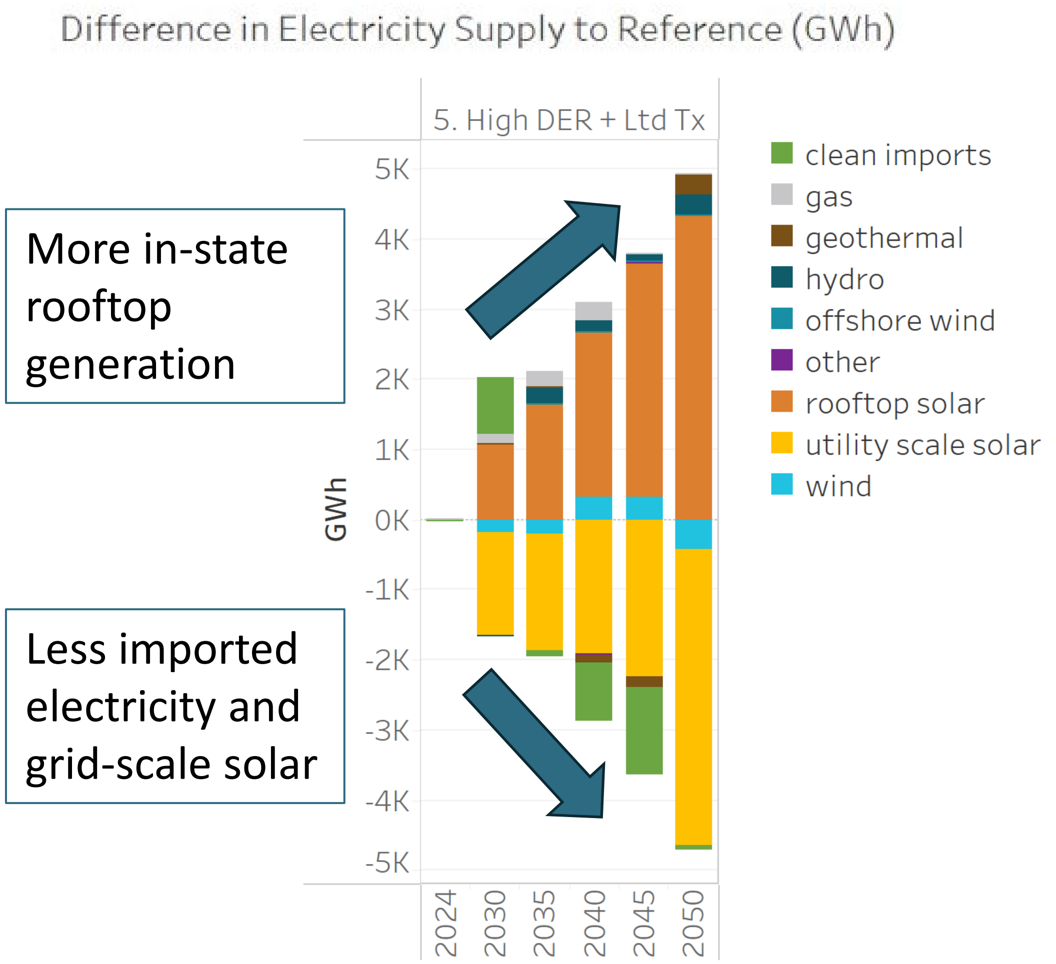
- Increased gas use
- Reduced electricity use
- Total energy demand 2% higher in 2030 and 6% higher in 2050
- Increases cost by $17B net present value
- Transition from fossil to clean may need to happen more gradually than shown



*Steam production is 55% geothermal and 35% biogas by 2050

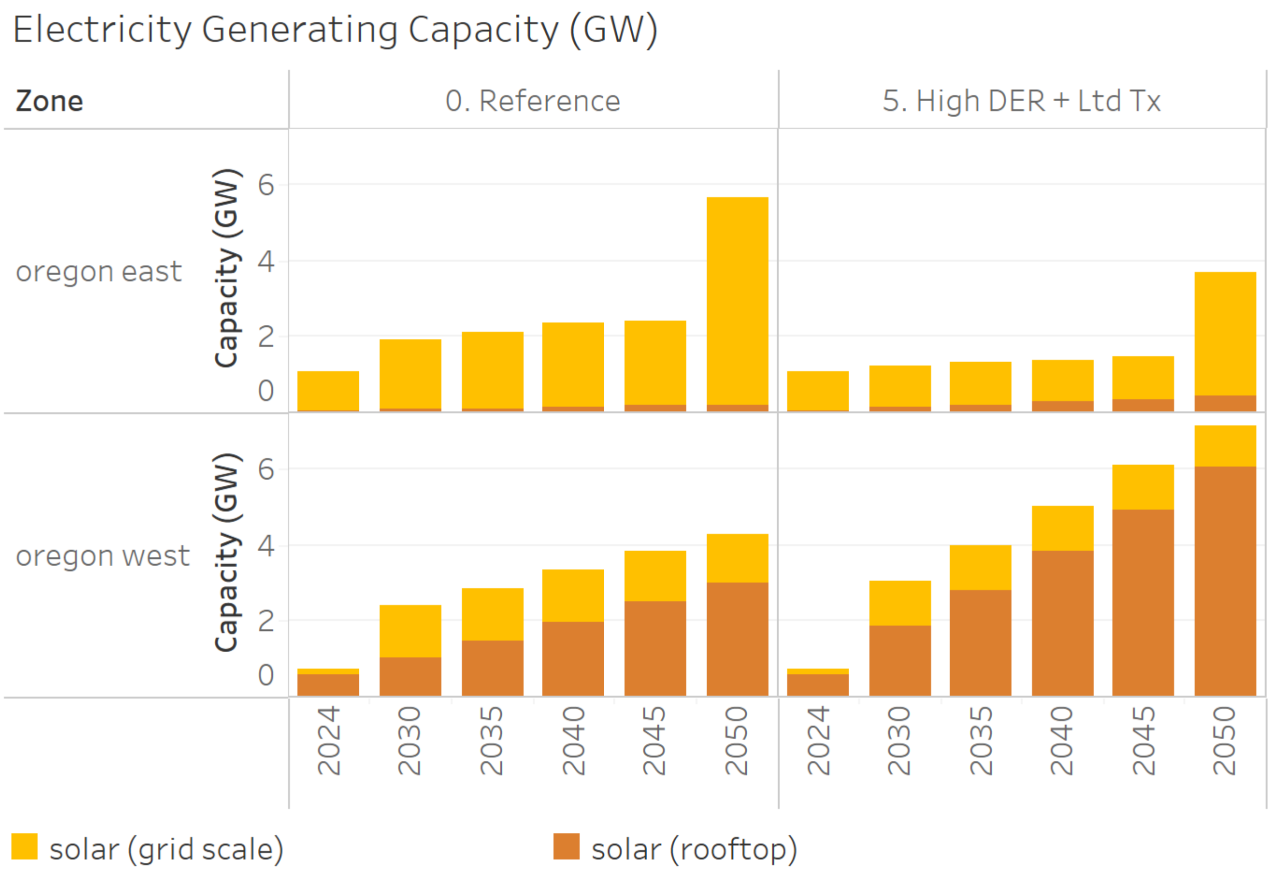
Rooftop solar in OR West reduces need for imports and grid-scale solar in OR East

- Rooftop solar additions displace some grid scale solar energy
- Majority of rooftop additions over the Reference Scenario are in Oregon West
- Majority of grid scale solar displaced is in Oregon East
- Rooftop solar also displaces some imported clean energy from other states



Increasing Rooftop Solar Substitutes for Some Grid Scale Solar Builds

- Increasing rooftop solar to 7 GW across Oregon rather than the 3 GW in the Reference Scenario reduces both the overall need and the pace of grid scale solar build
- May mitigate challenges to siting and permitting large additions of grid scale renewables



Flexible Loads Dependent on Participation in the Future

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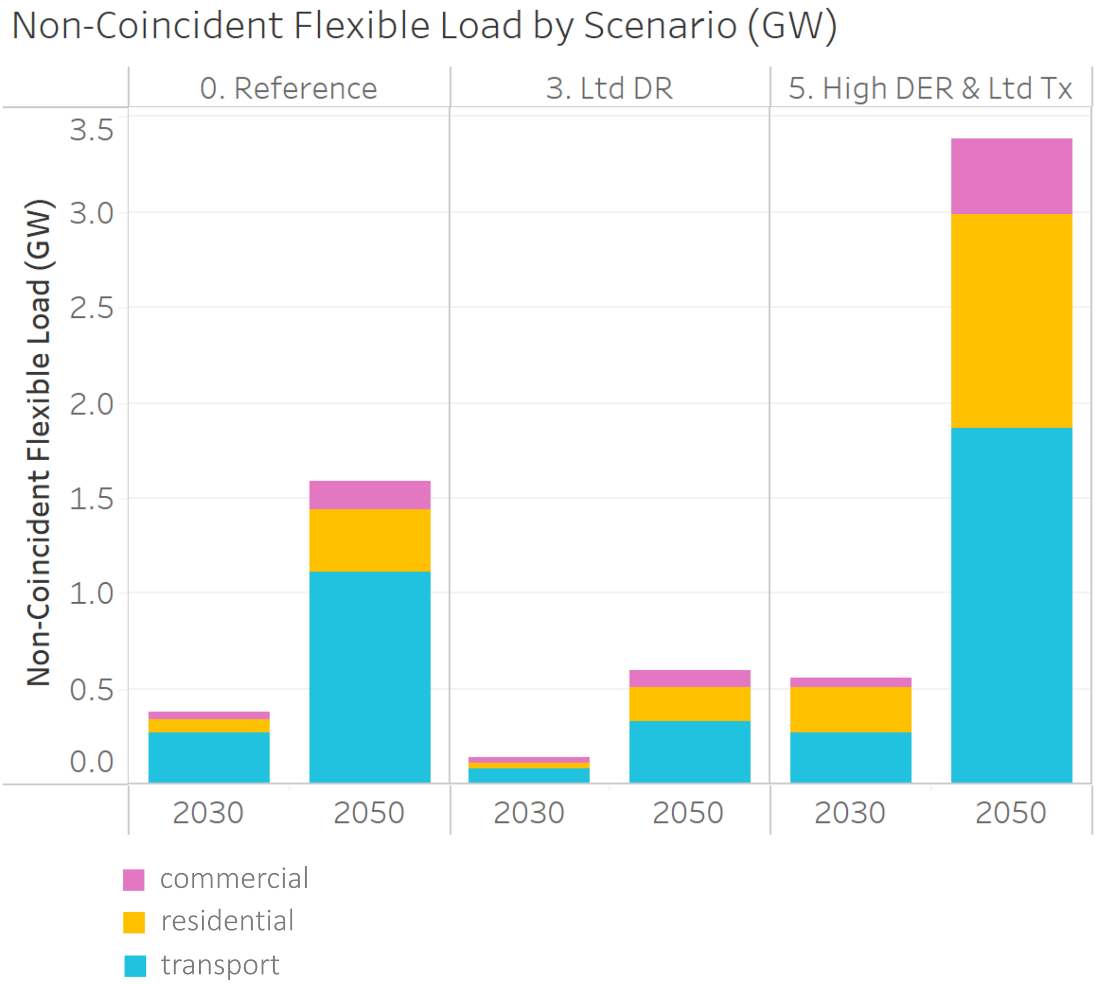
- The Reference Scenario assumes active participation of customers in demand response programs
- The capacity of flexible load contributions by 2050 will vary based on customer participation
- Residential and commercial buildings contribute to demand response through participating water heating, space heating, and air conditioning systems



Conclusions

Key Takeaways

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- Electrification and energy efficiency are key to reducing the size of the overall energy "pie" and to cost containment
- Fuels play a strategic role in the transition, with a shift toward clean fuel alternatives toward 2050
- All scenarios indicate a need to build infrastructure in Oregon
- Tech loads are the biggest driver of electricity demand growth but are also uncertain in when and where they could emerge