The BIG ISSUE
Transforming Our Transportation
SCENARIOS FOR WA & OR
How do you get around?
How does it make you feel?
How do you want to get around?
How do you want to feel during your commute, trips to the store, or other daily routes?
Transportation emissions are stubbornly high, pollute the air we all breathe, and are a big, big, issue.
WE CAN CHANGE THIS.

There are pathways and possibilities, but much needs to be done. And we need to start **now**.
HOW DO WE DO IT?
ELECTRIFY AND MORE.

We need to switch to 100% clean electricity (for almost everything) to move us and our goods around. And by reducing the vehicle miles we travel.

Cumulative carbon savings
Less electricity needed
Fewer chargers needed
Fewer crash deaths
More people using active transportation
WE HAVE CHOICES.

It’s possible to decarbonize everything through electrification, but this scenario has some significant costs.

<table>
<thead>
<tr>
<th></th>
<th>Electrification-only vs. combination</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cumulative CO₂ emissions</strong></td>
<td>2020-2050</td>
</tr>
<tr>
<td>2050 shown unless otherwise specified</td>
<td>40 Mt more</td>
</tr>
<tr>
<td><strong>Social cost of carbon</strong></td>
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</tr>
<tr>
<td></td>
<td>$3 B more</td>
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<td>$2,600 ($1,000) more</td>
</tr>
<tr>
<td><strong>Total annual personal transport spending in 2050 (2030)</strong></td>
<td>$40 ($14) B more</td>
</tr>
</tbody>
</table>

*Includes fare recovery
WE HAVE TO ACT BOLDLY AND QUICKLY.

All scenarios are grounded in rapid, policy-supported electrification, but the optimal path combines reducing vehicle miles traveled (VMT) with electrification creating broader social benefits beyond the obvious.
WHY THIS RESEARCH?

To better inform how we design and advocate for transportation policies and include *new analysis* on how reducing VMT impacts efforts to decarbonize.
WE HAVE A GREAT TEAM.

Research scoping and overall direction
Leah Missik
Vlad Gutman-Britten
Kelly Hall

Created the transportation model; modeled co-benefits
Val Hovland
Seth Monteith
Rubi Rajbanshi

Electricity sector modeling
Dan Aas
Clea Kolster
Robbie Shaw
METHODOLOGY
METHODOLOGY

Variables—Electrification

The model allows testing both the pace of adoption and the total rate of adoption.

*S-CURVE = pace and rate of adoption*
METHODOLOGY

Variables—Vehicle Miles Traveled (VMT)

All are further variable by geography.

- Personal vehicle miles traveled
- Transit mode use and cost/ridership
- Micromobility
- Walk, bike, trips avoided
- Freight miles

People per vehicle

Seattle 1.49 vs. WA Rural 1.42
Portland 1.5 vs. OR Rural 1.43

Seattle 10 vs. WA Rural 4
Portland 10 vs. OR Rural 4
METHODOLOGY

Geographies

Variables can be changed by geography, and results can also be analyzed this way.
METHODOLOGY

Health & Air Pollution

VOCs—Create smog, harm our lungs, can cause cancer
NOx—Can cause respiratory infections

PM 2.5—Can worsen lung and heart problems, linked to hospital admissions and mortality

Air pollution data from model

Health & Air Pollution

Scaled to 2050

Health outcomes in 2025 by geography

Health Outputs

$ Total Health Benefits (low & high)
$ Hospital Admits, All Respiratory
$ Work Loss Days
Minor Restricted Activity Days (and cost $)
Mortality (low & high)
Asthma Exacerbation

Work Loss Days
Electric Sector Modeling

This study uses E3’s RESOLVE model to generate optimal resource portfolios under alternative policy regimes. RESOLVE co-optimizes investments and operations to minimize total NPV of electric system cost over the study time horizon:

- Investments and operations optimized in a single stage to capture linkages between investment decisions and system operations
- Selects resources based on total value to the entire system, not just levelized cost of energy

Objective Function

Fixed Costs
- Renewables
- Energy storage
- EE & DR
- Thermal
- Transmission

Variable Costs
- Variable O&M
- Start costs
- Fuel costs
- Carbon

Decisions
- Investments
- System Operations

Constraints
- RPS Target
- GHG Target
- PRM
- Operations
- Resource Limits
Study Approach

This study takes a regional view of electricity supplies, building on three key prior studies: Pacific Northwest Low Carbon Scenario Analysis (2017), Resource Adequacy in the Pacific Northwest (2019), Northwest Zero-Emitting Resources Study (2020). The study uses E3’s RESOLVE model to optimize the portfolio of resources serving loads in the “Core NW” region.
Hourly transportation electrification charging loads

E3 shaped the annual loads provided by Hovland Consulting with outputs from the Electric Vehicles Load Shift Tool (EVLST). The EVLST tool uses trip data from the National Highway Transportation Survey to identify at what times of day different driver types will need to charge their vehicles, determines charging sessions such that each driver can meet their mobility needs, and identifies what share of total charging load can be shifted between hours when all drivers can still meet their mobility needs.
A REFERENCE CASE:

Business as usual
Greenhouse Gas Emissions

The reference case compared emissions in a “business as usual” situation to scenarios that limit global warming to what’s minimally necessary for climate stability.

This means a 95% reduction from 2020 levels needed by 2050 to limit warming to 2°C or below. These reductions align with the Washington Deep Decarbonization Pathways and the Clean Energy Transition Institute’s Pathways study for the NW.
REFERENCE CASE

Business as Usual

This case examines: GHG emissions, population, VMT & modes, air pollution, safety, costs, etc.

-11% of passenger fleet, ~23% of buses are electric by 2050. Freight does not electrify.
Vehicle Miles Traveled

In a business as usual case, we see a significant increase in total miles traveled for personal and freight travel.

Passenger miles traveled increases with population.

+30% increase
REFERENCE CASE

Vehicle Miles Traveled

In a business as usual case, we see a significant increase in total miles traveled for personal and freight travel.

**Freight miles traveled increases with economics and population.**

+45% increase
Electricity

We need to have a clean grid. Washington passed the 100% clean electricity law (2019’s Clean Energy Transformation Act), but Oregon does not have a similar law in place. We cannot meet our decarbonization goals for the Pacific Northwest until after Oregon passes a similar policy.
Health Benefits by Community Type

We do not experience harmful air pollution equally—a result of historic racist policies and practices like redlining, urban renewal districts, abuse of eminent domain, and inner-city highway construction, where racist policies have restricted and forced communities of color to move into concentrated, high-traffic areas next to highways, ports, railroads, and industrial facilities. As a result, communities of color and low-income communities face a disproportionate share of toxic air pollution and poor air quality.
REFERENCE CASE

People of Color & People of Color + Hispanic

REFERENCES

25-30% POC
REFERENCE CASE

Below 185% Poverty Level

30-60+% people in poverty

We referenced 185% of the poverty line based on the WA Environmental Health Disparities Map as well as 80% of the local area median incomes.
accelerating the transition to our clean energy future

REFERENCE CASE

Electricity

Resource Builds 2050

Energy Mix

ELECTRICITY BY THE NUMBERS

<table>
<thead>
<tr>
<th>System cost</th>
<th>$18.89 B</th>
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<tbody>
<tr>
<td>Total load (TWh)</td>
<td>198</td>
</tr>
<tr>
<td>Peak Capacity (GW)</td>
<td>36</td>
</tr>
</tbody>
</table>

- Total load (TWh): 198
- Peak Capacity (GW): 36
- System cost: $18.89 B

**Resource Builds 2050**

**Energy Mix**

- Hydro: 64%
- Solar: 5%
- Wind: 16%
- Customer PV: 0%
- Biomass: 2%
- Large Nuclear: 4%
- Gas CC GT: 1%
- Gas CC GT with CCS: 8%
THE SCENARIOS

We know we need to transition away from fossil fuels, but now do we get there?
Which path is ideal?
Background on electrification

Each of these core scenarios hold electrification targets constant (near-100% of vehicles are electric by 2050) but vary in the vehicle miles traveled (VMT). We can evaluate the impacts of changing VMT, but without near-100% electrification, decarbonization goals are not met.

Each scenario leads to different electricity needs.
Electrification: Load scenarios

Hovland Consulting provided three transportation electrification load scenarios. These scenarios vary the share of transportation demands met by different modes.
Electrification: Load scenarios

Transportation electrification increases regional load forecasts. Reference load growth is based on a combination of regional load forecasts (NWPCC 7th plan, PNUCC, BPA White Book, TEPPC) as described in Pacific Northwest Low Carbon Scenario Analysis (2017).
SCENARIO 1: AN IDEAL WORLD

Vehicle Miles Traveled Reduced
+ Electrification
WE CAN REDUCE OUR PERSONAL VEHICLE MILES AND ELECTRIFY.

Reducing VMT and electrifying transportation has many benefits and is the **optimal scenario** for overall broad social benefit.
PLUS WE CAN 
INCREASE SAFETY AND 
REDUCE COSTS.

Employing both decreased VMT and electrifying leads to greater total carbon reductions. This scenario takes ample policy change and planning.
SCENARIO 1: ↓ VMT + ⚡

Comparison: Vehicle Miles Traveled

Seattle would have to reduce VMT by 46% to match London.

Oregon would have to reduce VMT by 29% to match NY state.
SCENARIO 1: ↓ VMT + ⚡

Reducing Passenger Miles & Vehicle Miles Traveled

Assumes ~1.5 people per car and 4-10 people per bus.

<table>
<thead>
<tr>
<th></th>
<th>Passenger Miles Traveled Reduction</th>
<th>Equivalent Personal Vehicle Miles Traveled Reduction (with bus, walk, micromobility)</th>
<th>Equivalent to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>35%</td>
<td>47%</td>
<td>London (lower than NYC)</td>
</tr>
<tr>
<td>Suburban</td>
<td>35%</td>
<td>39%</td>
<td>Washington DC &amp; London average</td>
</tr>
<tr>
<td>Small city</td>
<td>15%</td>
<td>20%</td>
<td>New York state</td>
</tr>
<tr>
<td>Rural</td>
<td>10%</td>
<td>10%</td>
<td>States like CA, CT, NJ, IL</td>
</tr>
</tbody>
</table>

Miles Traveled Reduction

<table>
<thead>
<tr>
<th></th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freight</td>
<td>Other scenarios (EIA) have 8% reduction. This represents different economic growth scenarios.</td>
</tr>
<tr>
<td>Statewide</td>
<td>29% PMT reduction</td>
</tr>
</tbody>
</table>
SCENARIO 1: ↓ VMT + ⚡

Near-100% Electrification

This scenario combines high electrification rates with reduced vehicle miles traveled.
SCENARIO 1: ↓ VMT + ⚡

Greenhouse Gas Emissions

515 MMT total carbon emissions from 2020-2050, 475 MMT less than BAU = $41 billion less in social cost of carbon
SCENARIO 1: \(
\downarrow \text{VMT} + \downarrow \text{VMT} \) 

Greenhouse Gas Emissions

Traffic Emissions

- **97% reduction 2050 vs 2020**

Scope 1 Tailpipe Emissions

Scope 2 Electricity Emissions

MMt CO2e - Passenger+Freight
SCENARIO 1: ↓ VMT + ⚡

Electrification Infrastructure

**Vehicles**: Convert to EVs - Passenger + Freight

- Combustion vehicles
- OR rural
- OR sml city
- Port. suburb
- Portland
- WA rural
- WA sml city
- Seat. suburb
- Seattle

**Chargers**: 750,000 chargers needed

Total cost = $1.2—2.4 billion
SCENARIO 1: ↓ VMT + ⚡

ELECTRICITY BY THE NUMBERS

<table>
<thead>
<tr>
<th>System cost</th>
<th>$18.89 B + $5.63 B = $24.52 B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total load (TWh)</td>
<td>198 +39</td>
</tr>
<tr>
<td>Peak Capacity (GW)</td>
<td>36 +4.9</td>
</tr>
</tbody>
</table>

**Resource Builds 2050**

**Energy Mix**

- **Hydro**: 54%
- **Solar**: 5%
- **Wind**: 19%
- **Customer PV**: 1%
- **Biomass**: 1%
- **Large Nuclear**: 4%
- **Gas CCGT with CCS**: 15%
- **Gas CCGT**: 1%
- **Conventional DR Storage**: 1%
- **Nuclear Relicensing**: 1%
- **New Peaker**: 1%
- **Geothermal**: 1%
- **Wind**: 1%
- **Li-Ion Battery Storage**: 1%
- **Small Hydro**: 1%
SCENARIO 1: \(\downarrow \) VMT + Lightning bolt

Personal Transportation Spending

A lot of personal transportation costs are associated with vehicle ownership and use. This scenario shows overall reduced costs with lower fuel costs from switching to EVs and by folks not owning a vehicle or driving less (walking, biking, or using transit).

Reductions compared to business as usual ~\(\$4,370\) per person per year saved
### SCENARIO 1: \(\downarrow\) VMT + ⚡

Health Benefits from Reduced Tailpipe Emissions

Change vs. Business as Usual

<table>
<thead>
<tr>
<th>Metric</th>
<th>2025</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ Total Health Benefits (low-high)</td>
<td>$30 - $68 M</td>
<td>$278 - $626 M</td>
</tr>
<tr>
<td>$ Hospital Admits reduced, All Respiratory</td>
<td>$20 k</td>
<td>$186 k</td>
</tr>
<tr>
<td>$ Work Loss Days avoided</td>
<td>$83 k</td>
<td>$764 k</td>
</tr>
<tr>
<td>$ Minor Restricted Activity Days avoided</td>
<td>$210 k</td>
<td>$1941 k</td>
</tr>
<tr>
<td>Mortality avoided (low-high)</td>
<td>3 - 6</td>
<td>28 - 62</td>
</tr>
<tr>
<td>Asthma Exacerbation avoided</td>
<td>95</td>
<td>875</td>
</tr>
<tr>
<td>Work Loss Days avoided</td>
<td>460</td>
<td>4,265</td>
</tr>
<tr>
<td>Minor Restricted Activity Days avoided</td>
<td>2,700</td>
<td>25,100</td>
</tr>
</tbody>
</table>

*Team analysis using EPA’s COBRA model*
SCENARIO 1: \(\downarrow\) VMT + \(\uparrow\)

Total benefits for People of Color + Hispanic

These values presented are minimum values, as benefits may occur more proportionally to vulnerable communities.

**$88 million in avoided health costs by 2050**

(Seattle)

**176 reduced asthma attacks**

(Seattle)

<table>
<thead>
<tr>
<th>People of color + Hispanic with reduced CO₂, NOₓ, PM₂.₅</th>
<th>Health Benefits, $M average</th>
<th>Reduced Asthma Exacerbation</th>
<th>Work Loss Days Avoided</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seattle</td>
<td>8</td>
<td>16</td>
<td>81</td>
</tr>
<tr>
<td>Seat. suburb</td>
<td>5</td>
<td>9</td>
<td>45</td>
</tr>
<tr>
<td>WA sm city</td>
<td>7</td>
<td>7</td>
<td>47</td>
</tr>
<tr>
<td>WA rural</td>
<td>7</td>
<td>17</td>
<td>14</td>
</tr>
<tr>
<td>Portland</td>
<td>4</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Port. suburb</td>
<td>2</td>
<td>2</td>
<td>1</td>
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<td>OR sm city</td>
<td>12</td>
<td>22</td>
<td>5</td>
</tr>
<tr>
<td>OR rural</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
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</table>
Total benefits for low-income communities

These values presented are minimum values, as benefits may occur more proportionally to vulnerable communities.
SCENARIO 1: ↓ VMT + ⚡

Active Mobility

Compared to business as usual:

**1 million** more people using buses

**250,000** more people walking, biking, or using micromobility options
SCENARIO 1: VMT + ⚡

Crash Fatalities

205 lives are saved in 2050 (and 42 in 2030) as a result of reduced VMT.

Small cities and rural areas in OR have high fatality rates
SCENARIO 1: ↓ VMT + ⚡

Annual Direct Costs

Reducing VMT saves on road costs, but requires more spending on transit.

### Road costs

<table>
<thead>
<tr>
<th></th>
<th>Business as usual</th>
<th>Scenario 1: VMT reduction + Electrification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Road costs</strong></td>
<td>$9.7 B</td>
<td>$7.4 B</td>
</tr>
<tr>
<td><strong>Transit costs</strong></td>
<td>+ $5.1 B</td>
<td>+ $7.6 B</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$14.8 B</td>
<td>$15 B</td>
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</table>

### Personal transportation costs

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<tr>
<td><strong>Personal cost</strong></td>
<td>$12,096</td>
<td>$7,720</td>
</tr>
<tr>
<td><strong>Net savings</strong></td>
<td></td>
<td>$4,376 net savings</td>
</tr>
</tbody>
</table>
SCENARIO 2:
100% ELECTRIC (ALMOST)

Electrification only
COULD WE JUST GO 100% ELECTRIC?

A fully electrified transportation system yields significant health benefits with only zero emission vehicles on the road.
IT WOULD REQUIRE SIGNIFICANT CHANGE AND INVESTMENTS.

It requires nearly all vehicles to be electric by 2050. Ultimately electrification-only does not have as many benefits as combining with reducing vehicle miles traveled.
SCENARIO 2: Near 100%

Near-100% electrification & business as usual VMT

What if we just made everything electric and kept our behavior the same? Could we still meet our decarbonization goals?
SCENARIO 2: Near 100%

Greenhouse Gas Emissions

**Scope 1 Tailpipe Emissions**

**Scope 2 Electricity Emissions**
SCENARIO 2: 100% E

ELECTRICITY BY THE NUMBERS

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<tr>
<td>Peak Capacity (GW)</td>
<td>36 +9.7</td>
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</table>

Resource Builds 2050

Energy Mix

- Solar 4%
- Wind 13%
- Customer PV 1%
- Biomass 1%
- Large Nuclear 4%
- Gas CC GT 1%
- Gas Peaker 0%
- Gas CC GT with CCS 18%
- Hydro 52%

System cost $18.89 B + $7.4 B = $26.29 B
Total load (TWh) 198 +59
Peak Capacity (GW) 36 +9.7
Health Benefits from Reduced Tailpipe Emissions

This scenario shows most tailpipe-related health benefits are similar by 2050, but fewer health benefits accrue in the short term.
Total benefits for People of Color + Hispanic

These values presented are minimum values, as benefits may occur more proportionally to vulnerable communities.

$88 million in avoided health costs by 2050
(Seattle)

874 work loss days avoided
(Seattle)

15k fewer than VMT + electrification scenario by 2050

k people of color + Hispanic with reduced CO2, NOx, PM2.5

Health Benefits, $M average

Reduced Asthma Exacerbation

Work Loss Days Avoided
Total benefits for low-income communities

These values presented are minimum values, as benefits may occur more proportionally to vulnerable communities.
Personal Transportation Spending

According to the Consumer Expenditures Survey, gas and oil account for 22% of personal transportation spending on the West Coast. Depending on location and driving habits, people could see $1,000-2,000 in annual savings due to the lower cost of fueling an EV compared to a gas—or diesel—powered vehicle.

Reductions associated with the lower costs of EV vs. ICE use

- $2,200 saved on gas/oil
- $200-250 spent on electricity

= Lower costs than BAU
But ~$2,600 more per year than VMT reduction scenario
SCENARIO 2: Near 100%

Electrification Infrastructure

As more electric vehicles hit the road, the ratio of these vehicles to public charging stations should be between 10 and 20 electric vehicles per station.

Vehicles

**Today**
- 78,000 EVs out of ~11 M vehicles
- Need ~14 M EVs
- 3.85 M more EVs compared to VMT reduction scenario

**2050**
- Need ~940,000 chargers
- 195,000 more compared to VMT reduction scenario

**Chargers**
- $1.6—3.1 B cost between now and 2050 ($50—100 M annually)

- **Today**
  - ~4,000 chargers now
- **2050**
  - Need ~940,000 chargers
  - 195,000 more compared to VMT reduction scenario
**SCENARIO 2: Near 100%**

Comparison: Electrification only

<table>
<thead>
<tr>
<th></th>
<th>2050 shown unless otherwise specified</th>
<th>Change from reduced VMT</th>
<th>Electrification + VMT reduction</th>
<th>Electrification only</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cumulative CO₂ emissions</strong> 2020-2050</td>
<td>♻ 40 Mt more</td>
<td>♻ 515 Mt</td>
<td>♻ 555 Mt</td>
<td></td>
</tr>
<tr>
<td><strong>Social cost of carbon</strong>, 2020-2050</td>
<td>♻ 3 B more</td>
<td>♻ $37 B</td>
<td>♻ $40 B</td>
<td></td>
</tr>
<tr>
<td><strong>Electrical power need</strong></td>
<td>♣ 11 TWh more</td>
<td>♣ 42 TWh</td>
<td>♣ 53 TWh</td>
<td></td>
</tr>
<tr>
<td><strong>Chargers</strong></td>
<td>♣ 190 k more</td>
<td>♣ 750 k</td>
<td>♣ 940 k</td>
<td></td>
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<tr>
<td><strong>$ for chargers</strong> (cumulative, low-high range)</td>
<td>♠ $300-700 M more</td>
<td>♠ $1.2-2.4 B</td>
<td>♠ $1.6-3.2 B</td>
<td></td>
</tr>
<tr>
<td><strong>Annual crash fatalities in 2050 (2030)</strong></td>
<td>♡ 205 (42) more</td>
<td>♡ 874 (863)</td>
<td>♡ 1,070 (904)</td>
<td></td>
</tr>
<tr>
<td><strong>Electric vehicles</strong></td>
<td>♠ 3.8 M more</td>
<td>♠ 10.4 M</td>
<td>♠ 14.2</td>
<td></td>
</tr>
<tr>
<td><strong>People walking, biking, or micro-mobility</strong></td>
<td>♠ 250k fewer</td>
<td>♠ 700k</td>
<td>♠ 450k</td>
<td></td>
</tr>
<tr>
<td><strong>People using buses</strong></td>
<td>♠ 1 M fewer</td>
<td>♠ 2 M</td>
<td>♠ 1 M</td>
<td></td>
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<tr>
<td><strong>Annual public road (no transit) spending in 2050 (2030)</strong></td>
<td>♠ $2.1 ($0.5) B more</td>
<td>♠ $7.4 ($7.3) B</td>
<td>♠ $9.5 ($7.8) B</td>
<td></td>
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<tr>
<td><strong>Annual transit expenditures</strong>* in 2050 (2030)</td>
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<td>♠ $7.6 ($5.6) B</td>
<td>♠ $5.1 ($4.1) B</td>
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<tr>
<td><strong>Annual per person transport spending in 2050 (2030)</strong></td>
<td>♠ $2,600 ($1,000) more</td>
<td>♠ $7,700 ($10,800)</td>
<td>♠ $10,300 ($11,800)**</td>
<td></td>
</tr>
<tr>
<td><strong>Total annual personal transport spending in 2050 (2030)</strong></td>
<td>♠ $40 ($14) B more</td>
<td>♠ $119 ($143) B</td>
<td>♠ $159 ($157) B</td>
<td></td>
</tr>
</tbody>
</table>

*Includes fare recovery  
**Down from $12,350 in 2020

**200 fewer lives saved annually**

**Personal transportation spending grows by an additional $2,600**

**Society saves $3–4 B less**
Annual Direct Costs

Annual direct costs for electrification only scenario are $1.6 B more than VMT reduction + electrification

Scenario 1
Road costs: $7.4 B
Transit costs: $7.6 B
Incremental Electricity costs: $5.6 B
Total: $20.6 B

Scenario 2: Near 100% electric
Road costs: $9.5 B
Transit costs: $5.1 B
Incremental Electricity costs: $7.4 B
Total: $22 B

$1.2 B additional cost

Business as usual:
$12,096

Scenario 1:
$7,720
$4,376 net savings

Scenario 2: Near 100% electric:
$10,309
$1,787 net savings
SCENARIO 3: NOT OPTIMAL

Increase in Vehicle Miles Traveled + Electrification
WHAT HAPPENS IF EVERYONE DRIVES ELECTRIC, BUT DRIVES MORE MILES?

It’s possible to achieve full decarbonization, but this scenario is expensive and not ideal.
WHAT CAUSES US TO DRIVE MORE?

Poor land use decisions that increase sprawl and cause more driving, economic circumstances leading to more freight delivery, and potentially automation.
SCENARIO 3: ⬆ VMT + ⚡

An Increase in Vehicle Miles Traveled

VMT has risen over time, with OR and WA being exceptions. This scenario assumes they see a rise similar to other states historically.
### SCENARIO 3: ↑ VMT + ⚡

**Increasing Passenger Miles & Vehicle Miles Traveled**

<table>
<thead>
<tr>
<th></th>
<th>Passenger Miles Traveled Increase</th>
<th>Equivalent to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>Suburban</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>Small city</td>
<td>15%</td>
<td></td>
</tr>
<tr>
<td>Rural*</td>
<td>35%</td>
<td>North Dakota travel today, or change in travel in Florida or Ohio over 30 years</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Miles Traveled Increase</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freight</td>
<td>This represents an economic growth scenario (value from Freight Analysis Framework)</td>
</tr>
<tr>
<td>State-wide</td>
<td>22% PMT increase</td>
</tr>
</tbody>
</table>

* Rural VMT growing faster than urban, [https://www.psrc.org/sites/default/files/trend-vmt-201911.pdf](https://www.psrc.org/sites/default/files/trend-vmt-201911.pdf)
SCENARIO 3: \(\uparrow\) VMT + ⚡

Greenhouse Gas Emissions

30 MMT more carbon emissions
2020-2050 = $3 billion more in social cost of carbon compared to electrification only scenario
SCENARIO 3: \(\uparrow\) VMT +

**ELECTRICITY BY THE NUMBERS**

- System cost: $18.89 B + $8.85 B = $27.74 B
- Total load (TWh): 198 + 59 = 257
- Peak Capacity (GW): 36 + 9.9 = 45.9

**Resource Builds 2050**

<table>
<thead>
<tr>
<th>Resource</th>
<th>Reference</th>
<th>VMT Increase + Electrification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Li-Ion Battery Storage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCGT Repowering</td>
<td></td>
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<td>New Peaker</td>
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<td></td>
</tr>
<tr>
<td>Geothermal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCGT with CCS 100% Capture Rate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Energy Mix**

- Hydro: 50%
- Wind: 19%
- Customer PV: 1%
- Biomass: 1%
- Large Nuclear: 3%
- Gas CCGT: 1%
- Gas Peaker: 0%
- Gas CCGT with CCS: 21%
Health Benefits from Reduced Tailpipe Emissions

By 2050, tailpipe-related health benefits are similar since in both scenarios, nearly everything is electrified, meaning tailpipe pollution is largely eliminated. But if we drive more in the short term, we’ll see fewer benefits.

<table>
<thead>
<tr>
<th>Health Benefit</th>
<th>Change with increased VMT, 2050</th>
<th>Electrification + VMT reduction, 2050 (2025)</th>
<th>Electrification + VMT increase, 2050 (2025)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ Total Health Benefits (low-high)</td>
<td>~similar</td>
<td>$626 – $278 M ($68 – $30 M)</td>
<td>$620 – $274 M ($52 – $22 M)</td>
</tr>
<tr>
<td>$ Hospital Admits reduced, All Respiratory</td>
<td>~similar</td>
<td>$186 k ($20 k)</td>
<td>$184 k ($15 k)</td>
</tr>
<tr>
<td>$ Work Loss Days avoided</td>
<td>~similar</td>
<td>$764 k ($83 k)</td>
<td>$757 k ($63 k)</td>
</tr>
<tr>
<td>$ Minor Restricted Activity Days avoided</td>
<td>~similar</td>
<td>$1,941 k ($210 k)</td>
<td>$1,923 k ($161 k)</td>
</tr>
<tr>
<td>Mortality avoided (low-high)</td>
<td>~similar</td>
<td>28 – 62 (3 – 6)*</td>
<td>28 – 61 (3 – 6)*</td>
</tr>
<tr>
<td>Asthma Exacerbation avoided</td>
<td>~similar</td>
<td>875 (95)</td>
<td>870 (75)</td>
</tr>
<tr>
<td>Work Loss Days avoided</td>
<td>40 fewer</td>
<td>4,265 (460)</td>
<td>4,225 (355)</td>
</tr>
<tr>
<td>Minor Restricted Activity Days avoided</td>
<td>200 fewer</td>
<td>25,100 (2,700)</td>
<td>24,900 (2,100)</td>
</tr>
</tbody>
</table>

* Additional avoided mortality from reduced crashes is independently modeled (not part of the COBRA modeling) and additive to avoided mortality from reduced emissions.
SCENARIO 3: \( \uparrow \text{VMT} + \downarrow \text{E} \)

Total benefits for People of Color + Hispanic

These values presented are minimum values, as benefits may occur more proportionally to vulnerable communities.

30k fewer than Scenario 1 (VMT reduction + electrification) by 2050
SCENARIO 3: \textcolor{#008000}{↑} VMT + \textcolor{#0000ff}{⚡}

Total benefits for low-income communities

These values presented are minimum values, as benefits may occur more proportionally to vulnerable communities.

185\% Poverty level

<table>
<thead>
<tr>
<th>City</th>
<th>K people of in poverty with reduced CO2, NOx, PM2.5</th>
<th>Health Benefits, $M average</th>
<th>Reduced Asthma Exacerbation</th>
<th>Work Loss Days Avoided</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seattle</td>
<td>25,475</td>
<td>4</td>
<td>10</td>
<td>39</td>
</tr>
<tr>
<td>Seat. suburb</td>
<td>65,485</td>
<td>2</td>
<td>58</td>
<td>20</td>
</tr>
<tr>
<td>WA sm city</td>
<td>60,465</td>
<td>1</td>
<td>16</td>
<td>38</td>
</tr>
<tr>
<td>WA rural</td>
<td>60,415</td>
<td>1</td>
<td>16</td>
<td>38</td>
</tr>
<tr>
<td>Portland</td>
<td>60,415</td>
<td>1</td>
<td>16</td>
<td>38</td>
</tr>
<tr>
<td>Port. suburb</td>
<td>35,215</td>
<td>1</td>
<td>10</td>
<td>37</td>
</tr>
<tr>
<td>OR sm city</td>
<td>50,350</td>
<td>0</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>OR rural</td>
<td>60,615</td>
<td>0</td>
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80\% AMI

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<td>15</td>
<td>31</td>
<td>110</td>
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<td>40</td>
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Roughly 0.5-1 million people benefit in almost every region

40k fewer than Scenario 1 (VMT reduction + electrification) by 2050

Total benefits for low-income communities

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185\% Poverty level

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<td>0</td>
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<td>40</td>
</tr>
</tbody>
</table>
Crash Fatalities

216 lives are lost in 2050 (and 37 in 2030) compared to BAU VMT. Even more lives (425 in 2050) are lost compared to the low VMT scenario. Crash fatalities are especially high in rural OR.
Personal Transportation Spending

This scenario shows higher spending due to more vehicle travel, as much as $4,676 more than the low VMT scenario. Still, increased electrification yields lower fuel costs but total transportation costs exceed business as usual by approximately $296 annually.
Electrification Infrastructure

As more electric vehicles hit the road, the ratio of these vehicles to public charging stations should be between 10 and 20 electric vehicles per station.

**Vehicles**

![Graph showing the increase in EVs from 2020 to 2050 for different regions.](image)

*6.7 M more EVs*

**Chargers**

- **$1.8—3.6 B cost between now and 2050 ($0.6—1.2 B more than Scenario 1)**
- **350,000 more compared to Scenario 1**
Annual Direct Costs

Annual direct costs for increased VMT scenario are $3.8 B more than VMT reduction.

### Road costs
- **Scenario 1:** $7.4 B
- **Scenario 3:** $10.9 B

### Transit costs
- **Scenario 1:** $7.6 B
- **Scenario 3:** $4.6 B

### Incremental Electricity costs
- **Scenario 1:** $5.6 B
- **Scenario 3:** $8.9 B

**Total Costs**
- **Scenario 1:** $20.6 B
- **Scenario 3:** $24.4 B

**Additional Cost**
- $3.8 B

### Personal transportation costs

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Cost</th>
<th>Net Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business as usual</td>
<td>$12,096</td>
<td></td>
</tr>
<tr>
<td>Scenario 1</td>
<td>$7,720</td>
<td>$4,376 net savings</td>
</tr>
<tr>
<td>Scenario 3: VMT Increase + Electrification</td>
<td>$12,392</td>
<td>$296 additional cost (vs. BAU)</td>
</tr>
</tbody>
</table>
**SCENARIO 3: ↑ VMT + ⚡**

Comparison: 
Increased VMT

<table>
<thead>
<tr>
<th></th>
<th>2050 shown unless otherwise specified</th>
<th>Change with increased VMT</th>
<th>Electrification + VMT reduction</th>
<th>EV + high VMT (esp. rural)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumulative CO₂ emissions 2020-2050</td>
<td>70 Mt more</td>
<td>515 Mt</td>
<td>585 Mt</td>
<td></td>
</tr>
<tr>
<td>Social cost of carbon, 2020-2050</td>
<td>$6 B more</td>
<td>$37 B</td>
<td>$43 B</td>
<td></td>
</tr>
<tr>
<td>Electrical power need</td>
<td>20 TWh more</td>
<td>42 TWh</td>
<td>62 TWh</td>
<td></td>
</tr>
<tr>
<td>Chargers</td>
<td>350 k more</td>
<td>750 k</td>
<td>1,100 k</td>
<td></td>
</tr>
<tr>
<td>$ for chargers (cumulative, low-high range)</td>
<td>$0.6-1.2 B more</td>
<td>$1.2-2.4 B</td>
<td>$1.8-3.6 B</td>
<td></td>
</tr>
<tr>
<td>Annual crash fatalities in 2050 (2030)</td>
<td>411 (77) more</td>
<td>874 (863)</td>
<td>1,285 (940)</td>
<td></td>
</tr>
<tr>
<td>Electric vehicles</td>
<td>6.7 M more</td>
<td>10.4 M</td>
<td>17.1 M</td>
<td></td>
</tr>
<tr>
<td>People walking, biking, or micro-mobility</td>
<td>250k fewer</td>
<td>700k</td>
<td>450 k</td>
<td></td>
</tr>
<tr>
<td>People using buses</td>
<td>1.2 M fewer</td>
<td>2 M</td>
<td>0.8 M</td>
<td></td>
</tr>
<tr>
<td>Annual public road (no transit) spending in 2050 (2030)</td>
<td>$3.5 ($8.8) B more</td>
<td>$7.4 ($7.3) B</td>
<td>$10.9 ($8.1) B</td>
<td></td>
</tr>
<tr>
<td>Annual transit expenditures* in 2050 (2030)</td>
<td>$3 ($1.8) B more</td>
<td>$7.6 ($5.6) B</td>
<td>$4.6 ($3.8) B</td>
<td></td>
</tr>
<tr>
<td>Annual per person transport spending in 2050 (2030)</td>
<td>~$4,700 ($1,800) more</td>
<td>~$7,700 ($10,800)</td>
<td>~$12,400 ($12,600)</td>
<td></td>
</tr>
<tr>
<td>Total annual personal transport spending in 2050 (2030)</td>
<td>$72 ($24) B more</td>
<td>$119 ($143) B</td>
<td>$191 ($167) B</td>
<td></td>
</tr>
</tbody>
</table>

*Includes fare recovery

**Comparison:**

- **Increased VMT**
- **Societal costs significantly increase**

### Notes
- **Comparative Analysis:**
  - Cumulative CO₂ emissions show a 70 Mt increase by 2050 compared to the baseline.
  - Social cost of carbon increases by $6 B, leading to a broader $37 B increment in electrification costs.
  - Electrical power needs rise by 20 TWh, emphasizing the growth in energy demand.
  - Chargers require an additional 350 k units, indicating a significant infrastructure expansion.
  - Costs for chargers are projected at $0.6-1.2 B, rising to $1.2-2.4 B or more.
  - Annual crash fatalities are predicted to increase by 411 (77) more fatalities in 2050, reflecting safety concerns.
  - Electric vehicle adoption is projected to see a 6.7 M increase, indicating mass market adoption.
  - Pedestrian and cycling mobility decreases by 250k, underscoring a shift towards higher VMT scenarios.
  - Annual public road spending increases by $3.5 ($8.8) B, denoting a substantial rise in urban infrastructure costs.
  - Transit expenditures rise by $3 ($1.8) B, signaling targeted investments in public transport.
  - Annual per person transport spending shows a significant rise, with estimates ranging from ~$4,700 ($1,800) to ~$7,700 ($10,800) more.
  - Total annual personal transport spending escalates by $72 ($24) B, underscoring a comprehensive rise in individual transport costs.

- **Impact Analysis:**
  - The increase in VMT leads to significant societal costs, including higher CO₂ emissions, increased crash fatalities, and greater infrastructure and transit expenditures.
  - Electrification and VMT reduction strategies are crucial in mitigating these impacts, highlighting the importance of sustainable urban planning and infrastructure development.

- **Future Considerations:**
  - Further research is needed to balance the transition to electric vehicles with sustainable urban planning and reducing VMT to mitigate environmental and societal costs.
  - Policymakers and urban planners must strategize comprehensive approaches to ensure a smooth transition to a clean energy future while minimizing adverse effects on public safety and infrastructure costs.

- **Conclusion:**
  - The increased VMT scenario demands robust infrastructure, electrification strategies, and comprehensive urban planning to ensure a sustainable and safe transition to a clean energy future.
SCENARIOS 1-3

Direct Costs Summary

VMT Reduction + Electrification
- Incremental Electricity Costs
- Road Costs
- Transit Costs

Electrification Only
- Incremental Electricity Costs
- Road Costs
- Transit Costs

VMT Increase + Electrification
- Incremental Electricity Costs
- Road Costs
- Transit Costs

+$1.4B

+$3.8B
ELECTRICITY SECTOR:

Summary & Sensitivities

Load Management & SMR Resource Option
accelerating the transition
to our clean energy future 
climate solutions

**ELECTRICITY SECTOR**

<table>
<thead>
<tr>
<th></th>
<th>Reference</th>
<th>VMT Reduction + electrification</th>
<th>Electrification Only</th>
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</tr>
</thead>
<tbody>
<tr>
<td>CCGT with CCS 100% Capture Rate</td>
<td>5,056</td>
<td>8,678</td>
<td>10,020</td>
<td>11,216</td>
</tr>
<tr>
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<td>539</td>
<td>539</td>
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<td>Wind</td>
<td>5,348</td>
<td>9,936</td>
<td>10,430</td>
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</tr>
<tr>
<td>Solar</td>
<td>5,104</td>
<td>5,196</td>
<td>5,104</td>
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<tr>
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<td>1,559</td>
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</tr>
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<td>CCGT Repowering</td>
<td>1,842</td>
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<td>1,842</td>
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<tr>
<td>Nuclear Relicensing</td>
<td>1,207</td>
<td>1,207</td>
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<td>758</td>
<td>1,464</td>
<td>2,116</td>
<td>3,163</td>
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</table>
Example: 2050
Daily Transportation Electrification Load

Baseline transportation electrification shape has a dual peak. This load shape assumes that there is widespread public and workplace charging by 2050.
accelerating the transition to our clean energy future
climate solutions

Resource Builds 2050

- Reference
- Electrification Only

ELECTRICITY BY THE NUMBERS

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ELECTRICITY SECTOR

Resource Builds 2050

- Li-ion Battery Storage
- CCGT Repowering
- Conventional DR Storage
- Solar
- Small Hydro

Energy Mix

- Solar 4%
- Wind 13%
- Hydro 52%
- Customer PV 1%
- Biomass 1%
- Large Nuclear 4%
- Gas CCGT 1%
- Gas Peaker 0%
- Gas CCGT with CCS 18%

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Load Flexibility in RESOLVE

RESOLVE can shift loads to reduce the total resource cost of the electricity system. In this study, that shift is assumed to reduce the capacity requirements of the NW electricity system. E3 drew parameters from EVLST to ensure that the amount of shifted load does not violate the condition that drivers meet their trip needs.
Electrification Only + Managed Load

**Resource Builds 2050**

**Energy Mix**

- **ELECTRICITY BY THE NUMBERS**
  
  - System cost: $18.89 B + $7.4 B + $-0.6 B = $26.32 B
  
  - Total load (TWh): 257
  
  - Peak Capacity (GW): 45.7 -3.0
ELECTRICITY BY THE NUMBERS

- System cost: $18.89 B
- $7.4 B
- $1.57 B
- Total load (TWh): 257
- Peak Capacity (GW): 45.7

Resource Builds 2050

Energy Mix - NuScale SMR Costs

- Nuclear SMR: 35%
- Wind: 9%
- Solar: 9%
- Biomass: 1%
- Large Nuclear: 3%
- Gas CCGT: 1%
- Hydro: 48%
ADDITIONAL SCENARIOS:
What are the other possibilities?
ADDITIONAL SCENARIOS

55% VMT Reduction but no additional electrification beyond BAU
55% VMT Reduction but with electrification

For the previous scenario to meet GHG goals we need:

- **97%** cars, light-duty
- **96%** medium- and heavy-duty freight
- **98%** buses

...to be electrified by 2050
55% VMT Reduction but with electrification

Vehicles

6.2 M more EVs

Personal Spending

~$4,775 annually (~$2,945 less than Scenario 1)

Public spending:

Rocks: $5.1 B ($2.3 B less than Scenario 1)
Transit: $8.3 B ($.7 B more than Scenario 1)

Combined difference = $1.6 B less
ADDITIONAL SCENARIOS

Slow Electrification Adoption

We cannot delay electrification uptake and still achieve climate goals.

How much slower of EV adoption?

80% cars, light-duty
90% buses
75% medium-duty freight
72% heavy-duty freight
...are electrified by 2050
ADDITIONAL SCENARIOS

Delayed Electrification

We cannot delay electrification uptake and still achieve climate goals.

5 years
MMt CO2e - Passenger+Freight

10 years
MMt CO2e - Passenger+Freight

15 years
MMt CO2e - Passenger+Freight

BAU VMT

Low VMT

6.7% short of goal
4.6% short of goal
41% reduction 2050 vs 2020
54% reduction 2050 vs 2020

28.2% short of goal
21.3% short of goal
53.9% short of goal
41.2% short of goal
## ADDITIONAL SCENARIOS

### Automation: VMT Increase

**Overall VMT increase of 20%**
- Higher in urban areas
- Non-linear increase

**Lower transit use**
- Shared automation

**Many assumptions**
- Did not speculate about safety, personal cost impacts

<table>
<thead>
<tr>
<th>2050 shown unless otherwise specified</th>
<th>Automation + VMT increase vs. electrification-only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumulative CO$_2$ emissions 2020-2050</td>
<td>15 Mt more</td>
</tr>
<tr>
<td>Social cost of carbon, 2020-2050</td>
<td>$2 B more</td>
</tr>
<tr>
<td>Electrical power need</td>
<td>9 TWh more</td>
</tr>
<tr>
<td>Chargers</td>
<td>155 k more</td>
</tr>
<tr>
<td>$ for chargers</td>
<td>$500 M more</td>
</tr>
<tr>
<td>Electric vehicles</td>
<td>3 M more</td>
</tr>
<tr>
<td>People using buses</td>
<td>230 k fewer</td>
</tr>
<tr>
<td>Annual public road (no transit) spending in 2050</td>
<td>$1.8 B more</td>
</tr>
<tr>
<td>Annual transit expenditures* in 2050</td>
<td>$300 M less</td>
</tr>
</tbody>
</table>
What’s missing?

Some elements were too complex to model or we lacked adequate data to do so:

- Job growth, benefits, and impacts
- Local economic impacts
- Land use impacts
- Scope 3 emissions
- Non-tailpipe pollution impacts
- Traffic congestion impacts and associated time spent
- Biofuels and hydrogen-based solutions
  - Principally for freight
  - Would alter electricity load impacts
KEY TAKEAWAYS:

What does all this mean?
accelerating the transition
to our clean energy future 
climate solutions
IT'S TIME TO ACT BIG AND ACT FAST.

We need to reduce vehicle dependence and electrify as much as we can as fast as we can.
ELECTRIFYING IS GOOD FOR US.

We can see improved health and air quality, reduce how much we spend to get around, and address climate change.
WE CAN CHOOSE OUR HEALTH AND OUR CLIMATE.

Increasing transit use, biking, and walking and reducing vehicle dependency leads to even more health, safety, and economic benefits.
100% CLEAN IS CLOSER THAN YOU THINK.

No matter which pathway we choose, rapid electrification is the foundation. We have the technology to begin this process, but we need strong policy support.
WHAT KIND OF POLICIES DO WE NEED?
WHAT KIND OF POLICIES DO WE NEED?

Need to support rapid electrification now

Must **invest more** in transit, active transportation, and other ways to reduce vehicle trips

Must **improve** our land use policies

Seek to **prioritize health, safety, climate, economy** in all our policies
THIS IS 100% POSSIBLE.

We can and should *electrify* (almost) everything and reduce our overall vehicle miles for our *collective health*, safety, economic well-being, and for a *stable climate*. 
APPENDIX
Renewables Supply Curve

- Renewables available to the region are based on a supply curve that captures regional and technology diversity options for development.
- Transmission adders reflect the need to ensure that new renewables built in the Northwest are deliverable to loads; scenarios with more renewables require more transmission investment.

Renewable Resource Supply Curve ($/MWh)

- Hydro
- Solar
- Wind
- Geothermal
- Tx

[Graph showing the renewable resource supply curve with different technologies and their costs per MWh.]
Energy Storage Costs

- **Pumped hydro storage**: up to 5,000 MW assumed to be available at a cost of $2,450/kW based on a survey of existing literature
  - Pumped hydro is assumed to have an effective capacity of 50%

- **Battery storage**: unlimited quantities of lithium-ion and flow batteries assumed to be available
  - Cost assumptions (current & future) derived from Lazard Levelized Cost of Storage v4.0, including high, mid and low-cost projections

---

**Li-Ion Battery All-In Costs ($/kWh)**

<table>
<thead>
<tr>
<th>Year</th>
<th>High</th>
<th>Mid</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>$900</td>
<td>$800</td>
<td>$700</td>
</tr>
<tr>
<td>2025</td>
<td>$750</td>
<td>$650</td>
<td>$550</td>
</tr>
<tr>
<td>2030</td>
<td>$600</td>
<td>$500</td>
<td>$400</td>
</tr>
<tr>
<td>2035</td>
<td>$450</td>
<td>$350</td>
<td>$250</td>
</tr>
<tr>
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<td>$300</td>
<td>$200</td>
<td>$100</td>
</tr>
<tr>
<td>2045</td>
<td>$150</td>
<td>$100</td>
<td>$50</td>
</tr>
</tbody>
</table>

**Flow Battery All-In Costs ($/kWh)**

<table>
<thead>
<tr>
<th>Year</th>
<th>High</th>
<th>Mid</th>
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<td>$100</td>
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Capital costs shown for 4-hr storage devices; RESOLVE can select optimal duration for energy storage resources.
All-in Levelized Fixed Costs

+ All resource costs are based on NREL ATB 2019
+ Each resource has its own financing assumptions which determine the annual levelized cost presented in the graph below: these are the fixed cost inputs into RESOLVE

*Renewable resources are also subject to supply curve cost adjustments
# Key Resource Cost Parameters in 2045

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility-Scale Solar PV (Single-axis tracking)</td>
<td>$980</td>
<td>$12</td>
<td>No fuel cost</td>
</tr>
<tr>
<td>Onshore Wind (TRG6 - ~36% CF)</td>
<td>$1,080</td>
<td>$35</td>
<td>No fuel cost</td>
</tr>
<tr>
<td>CGS Relicensing</td>
<td>$406</td>
<td>$162</td>
<td>“Must run” with scheduled maintenance outages</td>
</tr>
<tr>
<td>NREL ATB Nuclear Small Modular Reactors (SMR)</td>
<td>$5,650</td>
<td>$99</td>
<td>Uranium fuel; Heat rate of 10,000 Btu/kWh; Flexible operations</td>
</tr>
<tr>
<td>Gas Combustion Turbine (Frame) – Peaker Resource</td>
<td>$850</td>
<td>$12</td>
<td>NG fuel; Heat rate 12,000 Btu/kWh</td>
</tr>
<tr>
<td>CCGT with Carbon Capture and Storage (Post-Combustion 90-100% Capture)</td>
<td>$1,700</td>
<td>$33</td>
<td>NG fuel; Heat rate 8,000 Btu/kWh; Operations equivalent to CCGT</td>
</tr>
<tr>
<td>4-hour Li-Ion Battery</td>
<td>$590</td>
<td>$2</td>
<td>Round trip efficiency of 92%</td>
</tr>
<tr>
<td>Biogas (a drop-in fuel to gas units)</td>
<td>N/A</td>
<td>Equivalent to Gas CT</td>
<td>High fuel cost ~23$/MMBTU</td>
</tr>
</tbody>
</table>
The Levelized Cost of Firm Resource Energy based on 2045 Costs

- The LCOE of candidate resources gives a preview of resource selection (but is NOT a model input) to meet different energy needs e.g. peaker at low capacity factors and low-cost baseload energy at high capacity factors.

1. Above 15% cap factor, CGS is always the cheapest source of zero carbon energy.
2. Biogas is the cheapest source of zero carbon capacity i.e. peaker-type operation.
3. CCGT with CCS offers both lower cost capacity and energy, operating between 20-55% capacity factor.
4. If operated above 60% cap factor, nuclear SMRs (at NREL’s advanced nuclear cost estimates) can provide carbon-free energy at 70-100$/MWh.
Natural Gas Core NW Price Forecast

- Natural gas price projections based on SNL Forwards for prices up to 2035 and EIA Future Database beyond 2035
- NW Sumas Gas hub price most proximate to Core NW region
- In comparison, biomethane clearing price estimated at 23 $/MMBTU (see Slide 14)
ELCCs sourced from Resource Adequacy in the Northwest (2019)

**Diverse Wind (NW, MT, WY)**

**Solar**

**6-Hr Storage**

**Demand Response**

ELCC = Effective Load Carrying Capability = firm contribution to system peak load
Biomethane costs and quantities

Northwest Biomethane Supply Curve

Notes: 1) supply curves sourced from *Pacific Northwest Pathways to 2050*
2) biomethane costs in RESOLVE reflect a market clearing price of $23/ MMBtu