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.

2050 shown unless otherwise specified	Electrification-only vs. combination
Cumulative CO_2 emissions 2020-2050	40 Mt more
Social cost of carbon, 2020-2050	$3 B more
Electrical power need	11 TWh more
Chargers	190 k more
$ for chargers (cumulative, low-high range)	$300-700 M more
Annual crash fatalities in 2050 (2030)	205 (42) more
Electric vehicles	3.8 M more
People walking, biking, or micro-mobility	250k fewer
People using buses	1 M fewer
Annual public road (no transit) spending in 2050 (2030)	$2.1 ($0.5) B more
Annual transit expenditures* in 2050 (2030)	$2.5 ($1.5) B less
Annual per person transport spending in 2050 (2030)	$2,600 ($1,000) more
Total annual personal transport spending in 2050 (2030)	$40 ($14) B more

*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.

Support rapid electrification

Invest in transit and active transportation (biking, walking, and micromobility)

Improve our land use policies

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.

climate solutions

Research scoping and overall direction

Leah Missik

Vlad Gutman-Britten

Kelly Hall

Hovland Consulting LLC

Created the transportation model; modeled co-benefits

Val Hovland

Seth Monteith

Rubi Rajbanshi

Energy+Environmental Economics

Electricity sector modeling

Dan Aas

Clea Kolster

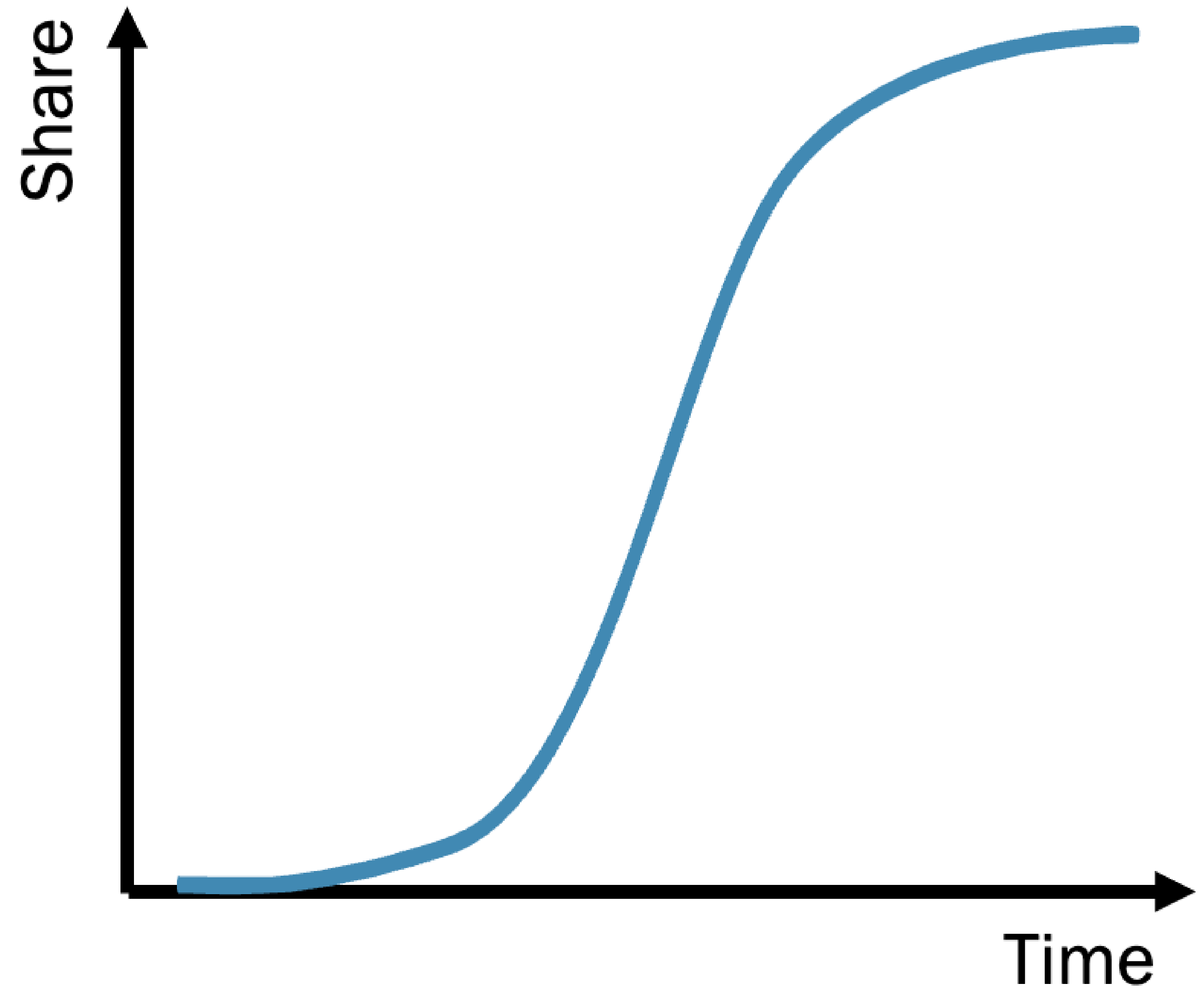
Robbie Shaw

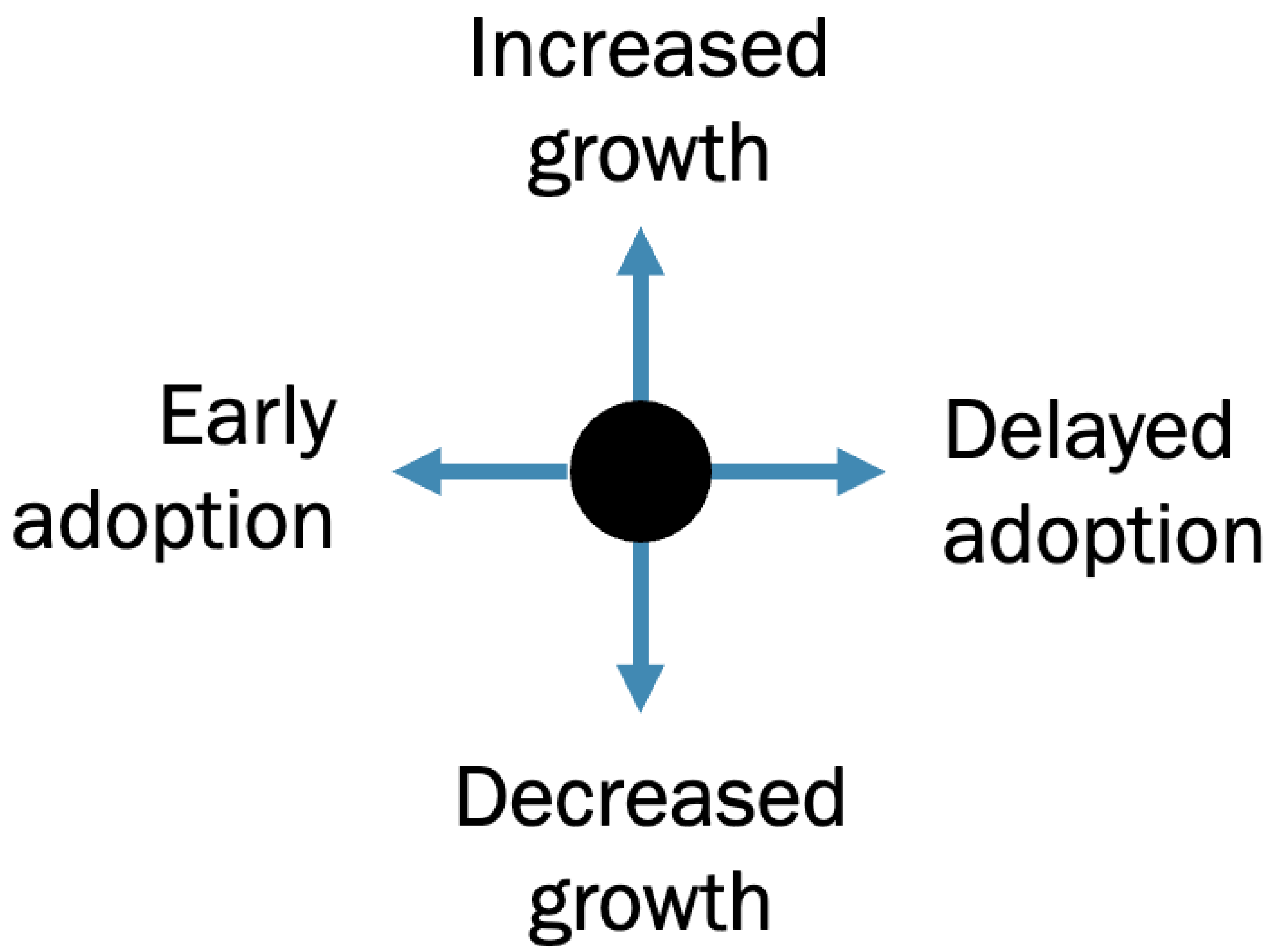
METHODOLOGY

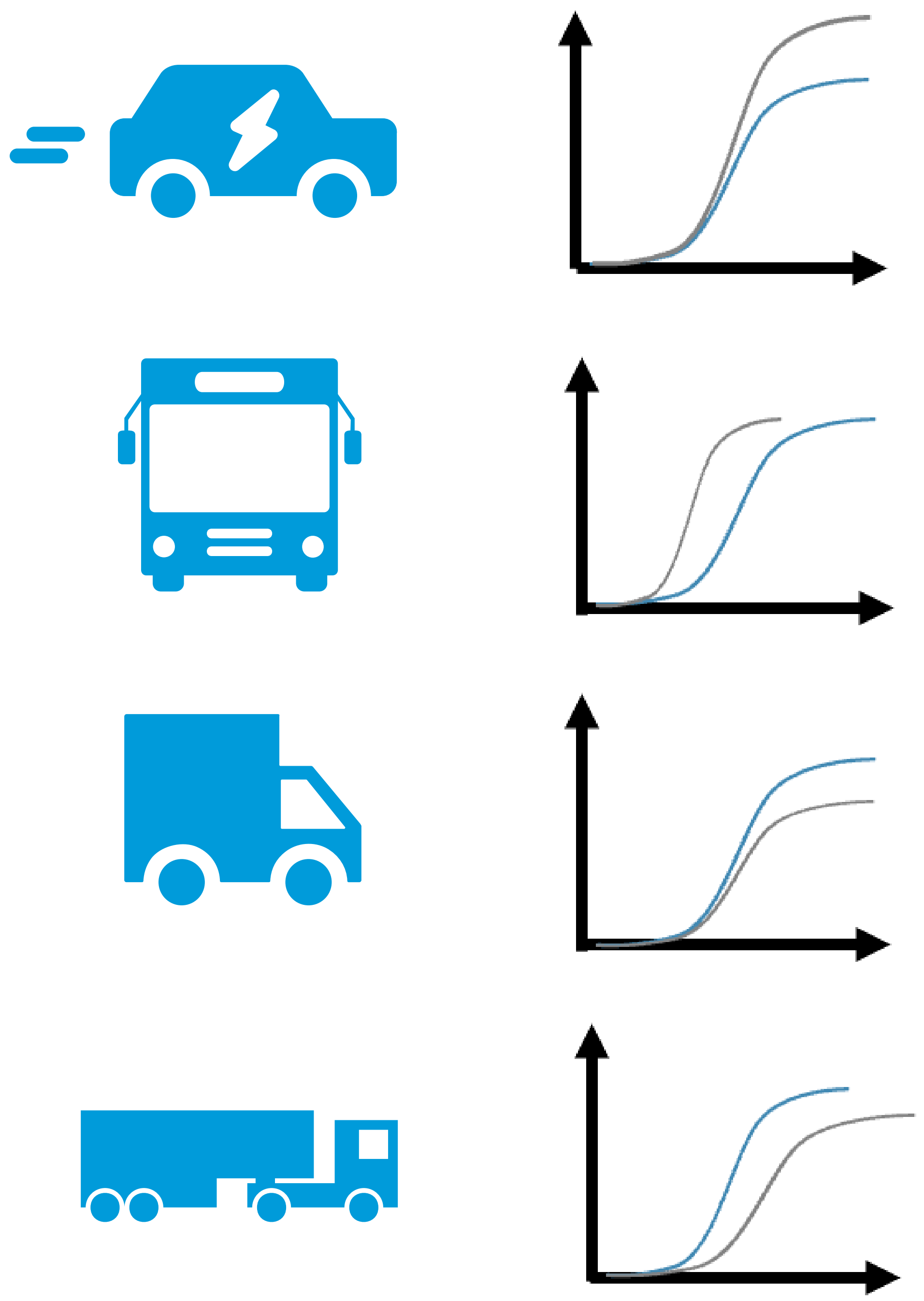
Variables—Electrification

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

S-CURVE = pace and rate of adoption







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.

Map created by
Hovland Consulting
for Climate Solutions

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 → COBRA Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool → **Health outcomes in 2025 by geography** → **Scaled to 2050**

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

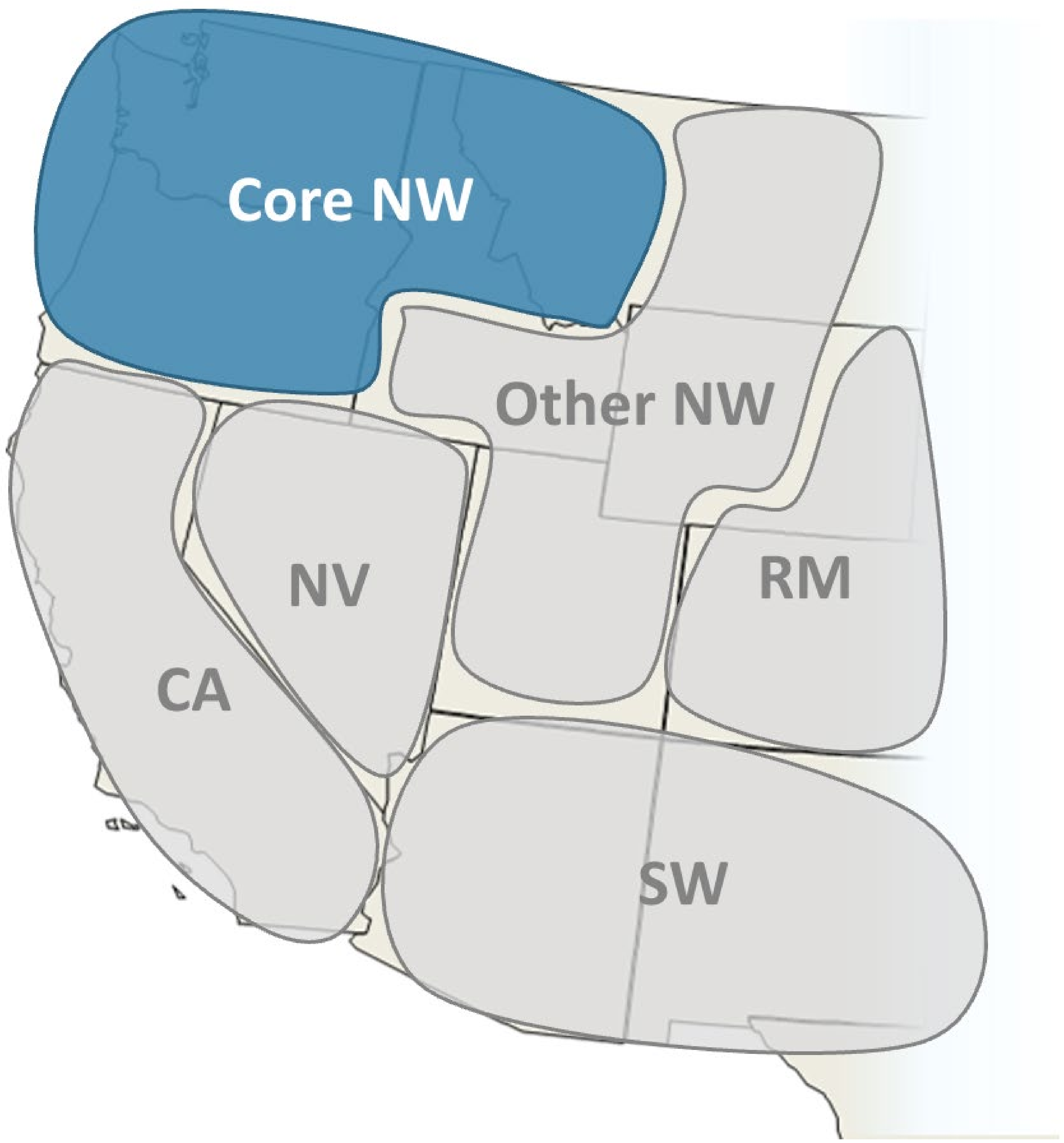
Investments ⇄ **System Operations**

Constraints

RPS Target
GHG Target
PRM
Operations
Resource Limits

Study Approach

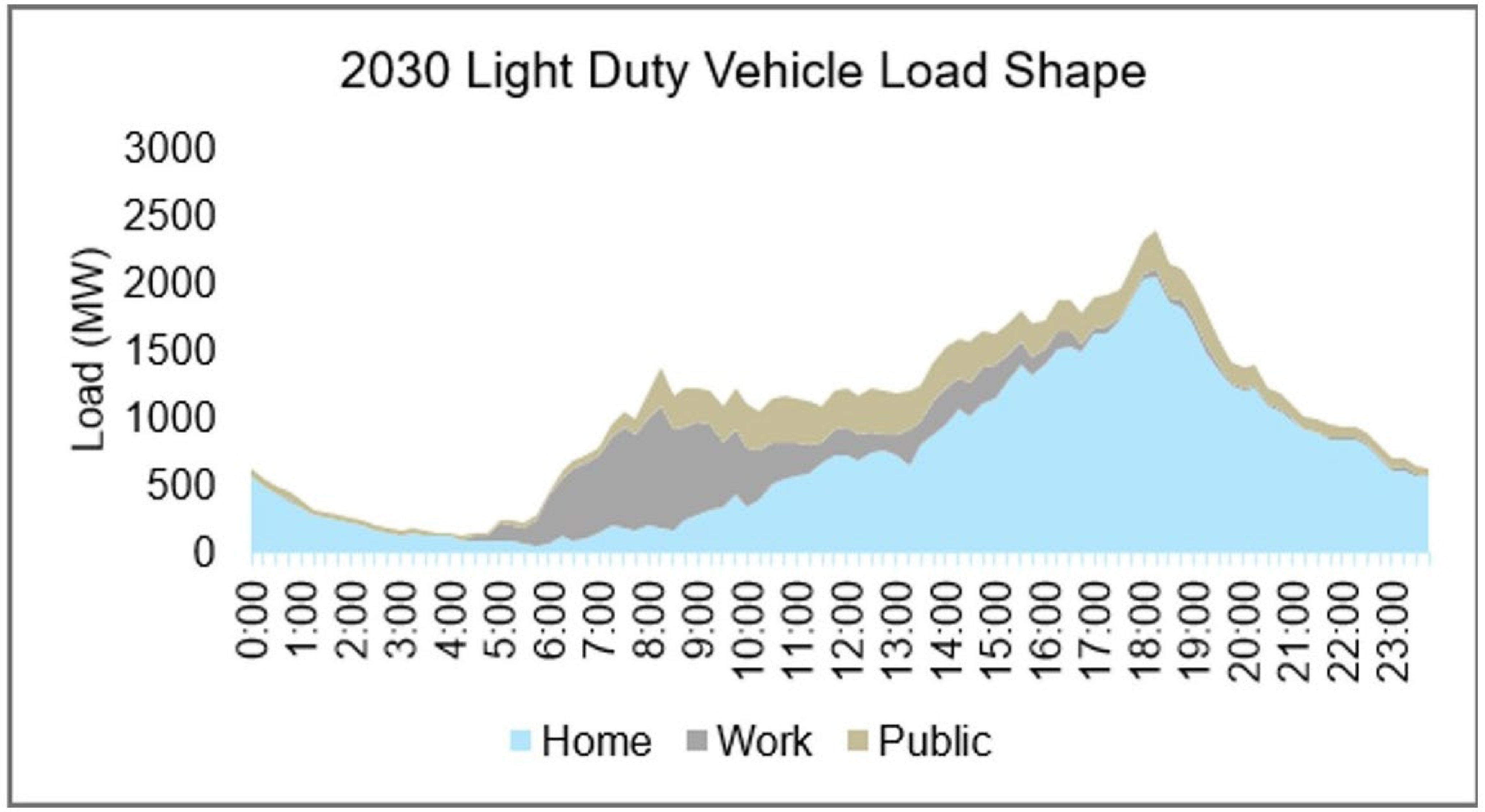
This study takes a regional view of electricity supplies, building on three key prior studies: Pacific Northwest Low Carbon Scenario Analysis (2017), Resource Adequacy in the Pacific Northwest (2019), Northwest Zero-Emitting Resources Study (2020). The study uses E3's RESOLVE model to optimize the portfolio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



METHODOLOGY

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:

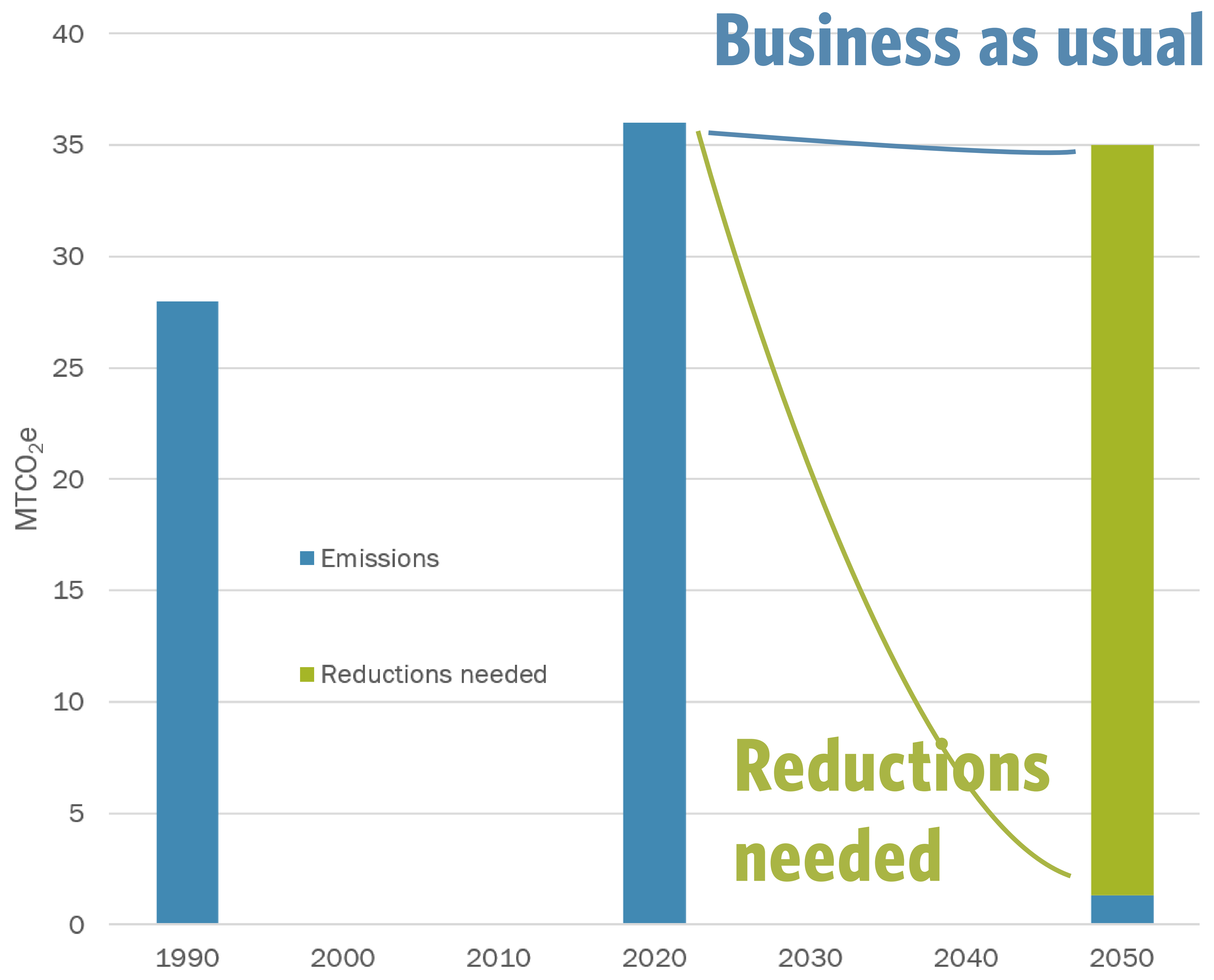
Business as usual

REFERENCE CASE

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 2C or below. These reductions align with the Washington Deep Decarbonization Pathways and the Clean Energy Transition Institute's Pathways study for the NW.



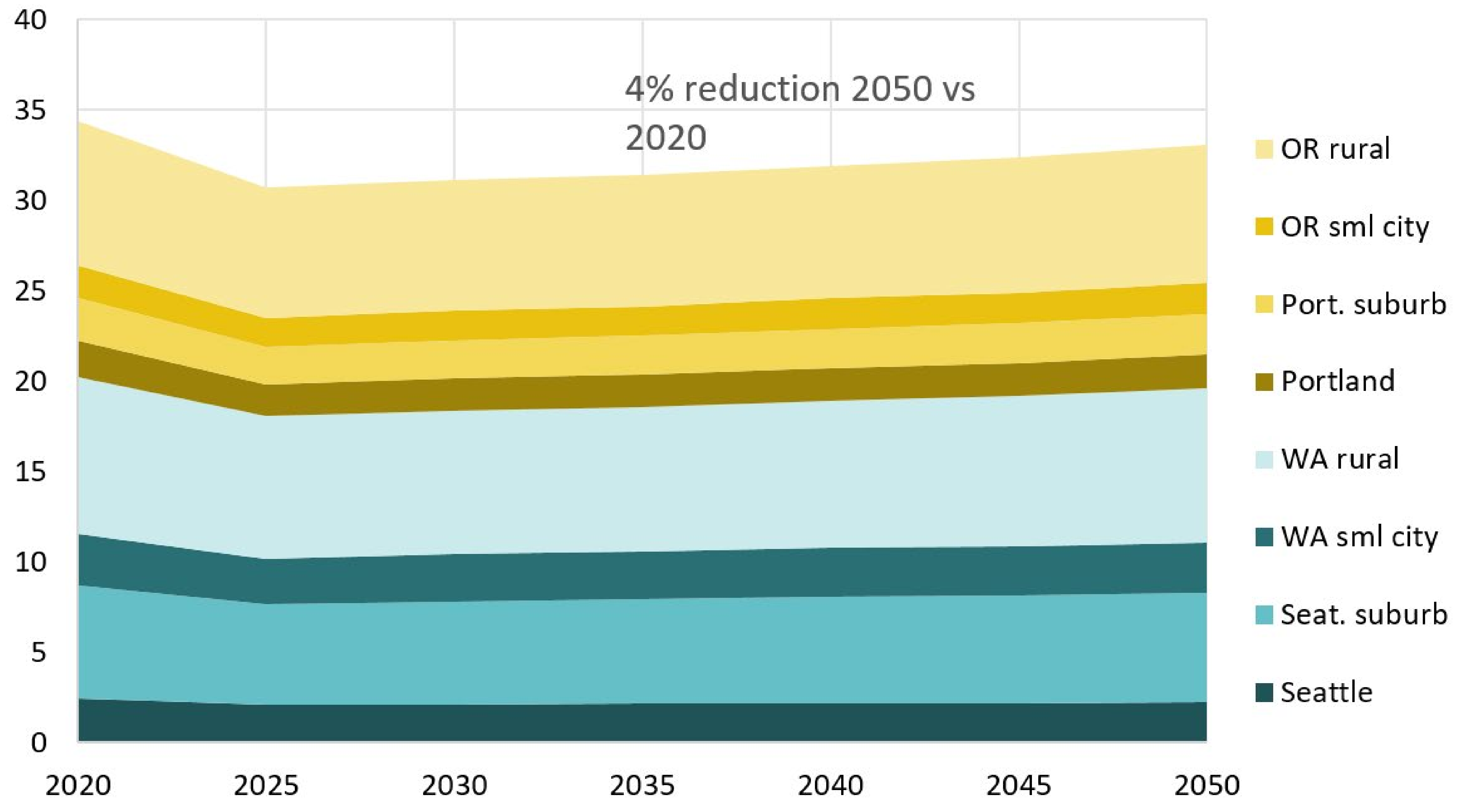
REFERENCE CASE

Business as Usual

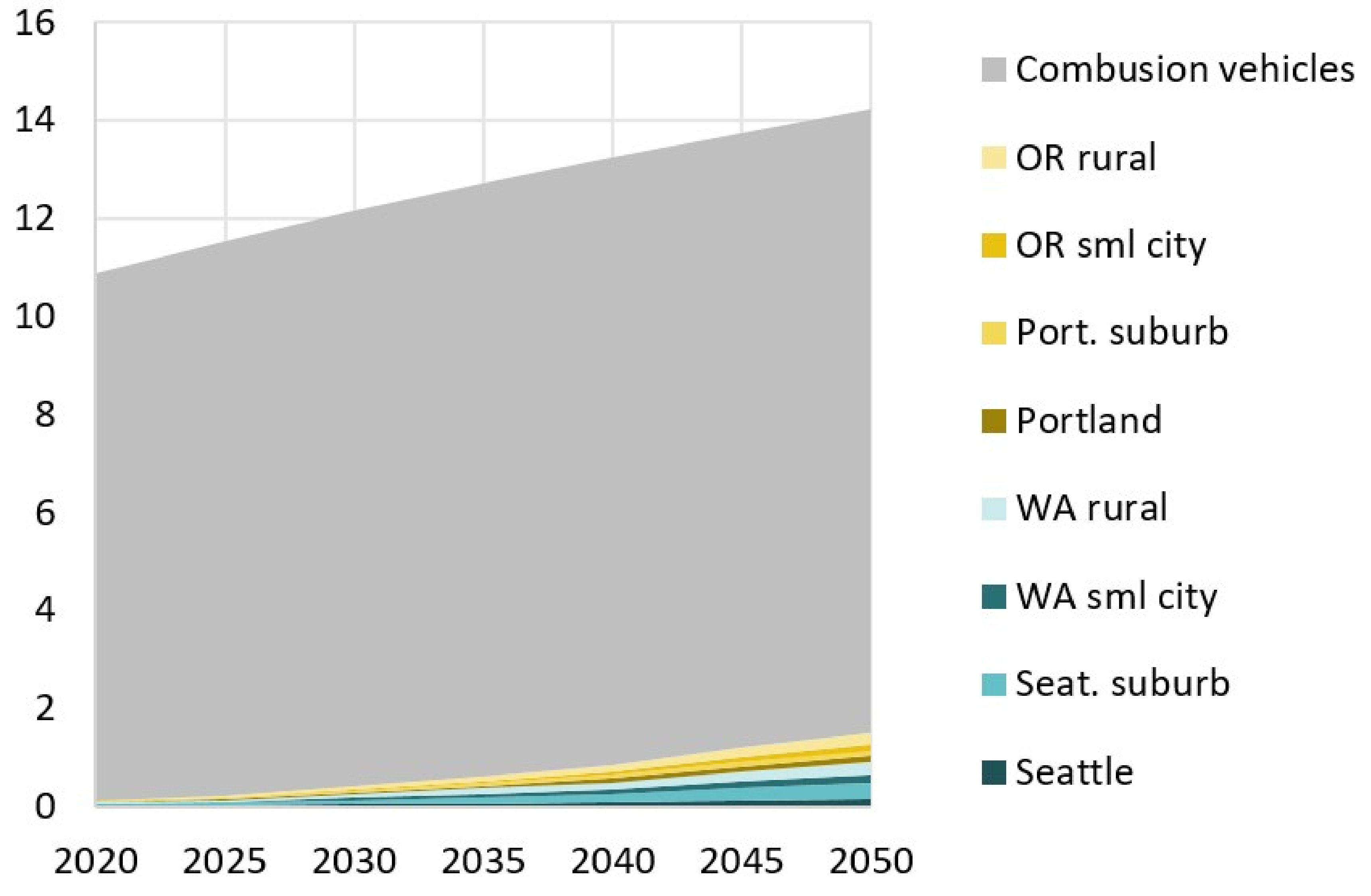
This case examines: GHG emissions, population, VMT & modes, air pollution, safety, costs, etc.

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

MMt CO2e - Passenger+Freight



M EVs - Passenger + Freight



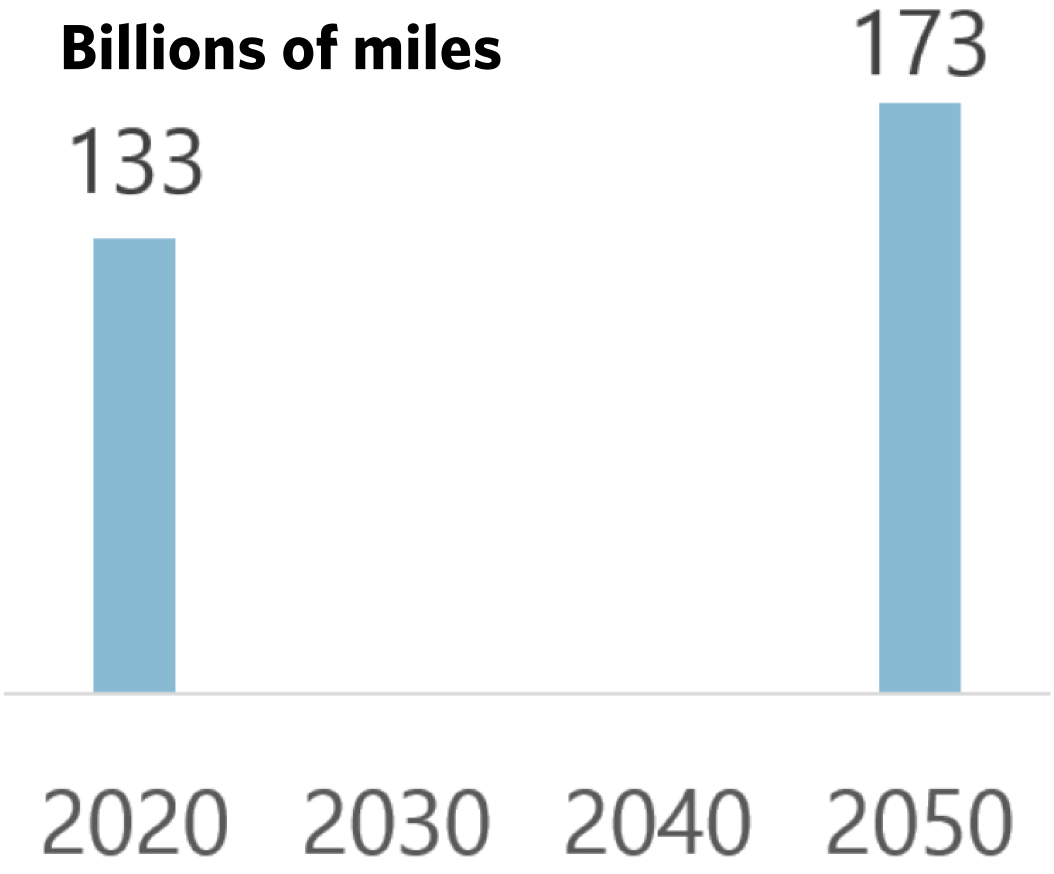
REFERENCE CASE

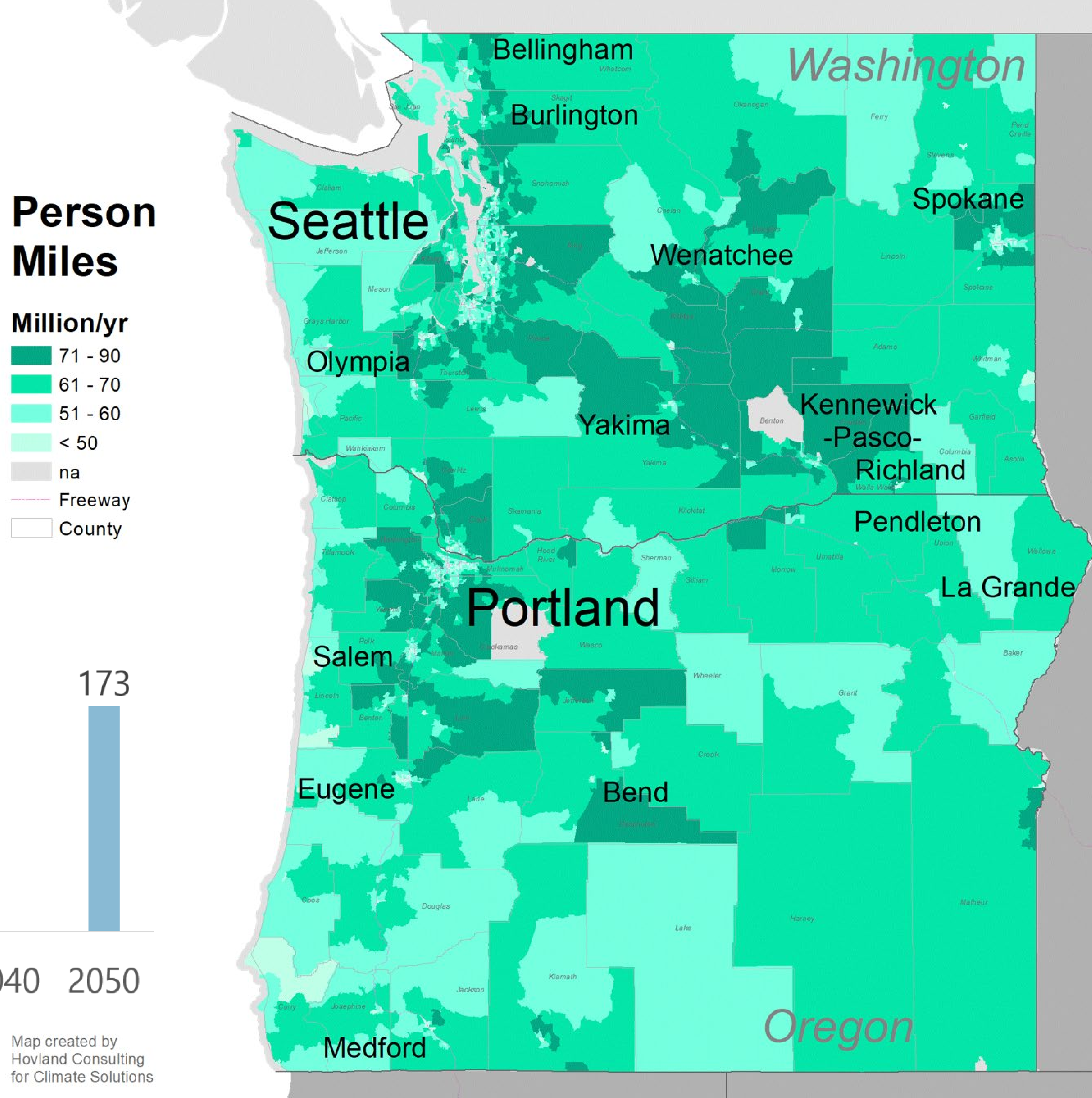
Vehicle Miles Traveled

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

Passenger miles traveled increases with population.

+30% increase





Map created by Hovland Consulting for Climate Solutions

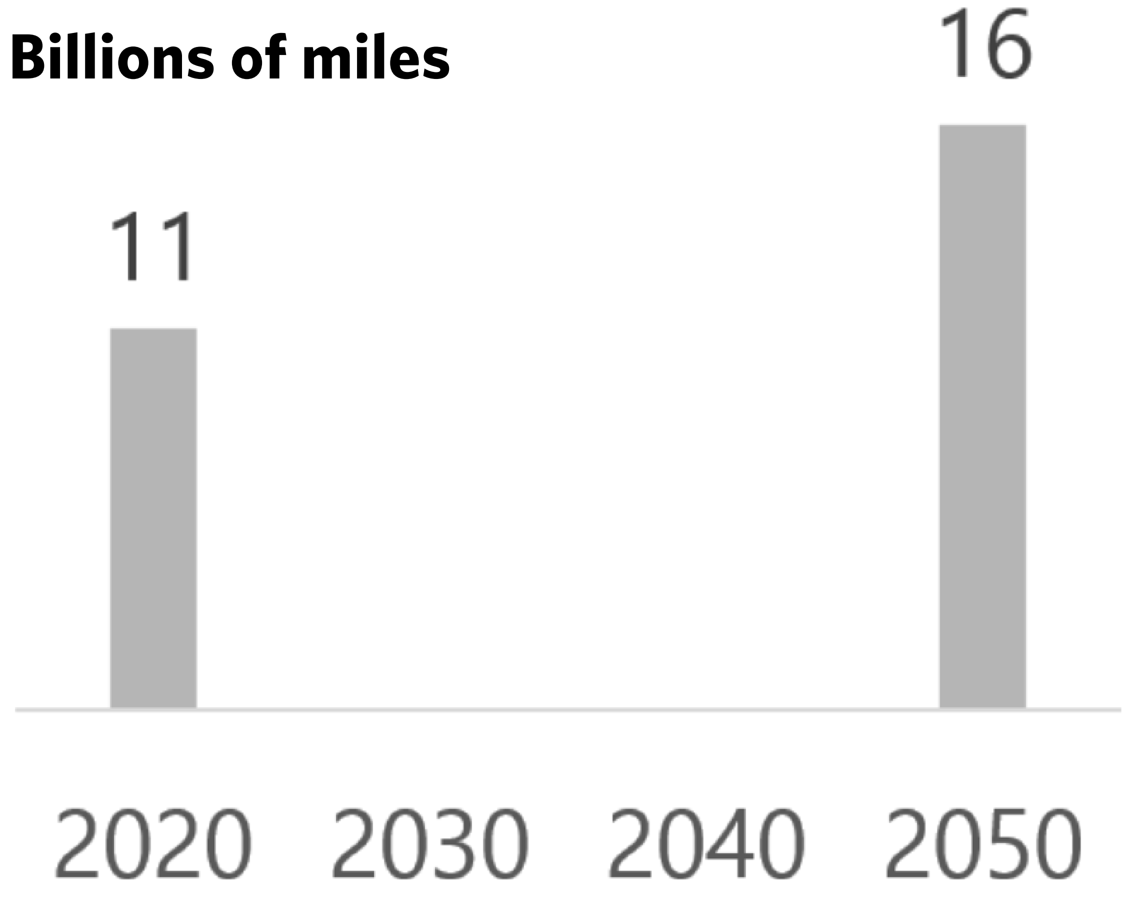
REFERENCE CASE

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

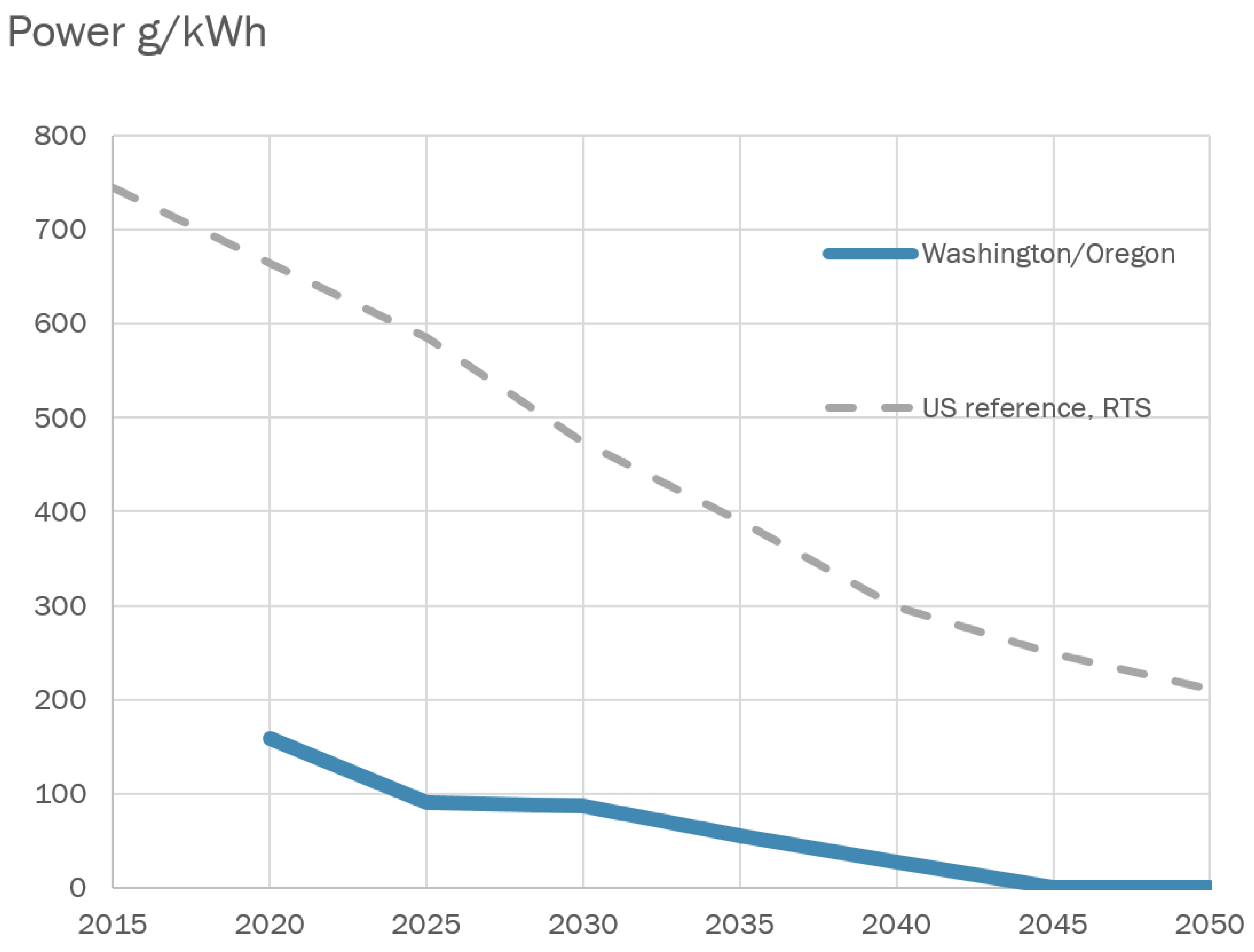


Map created by
Hovland Consulting
for Climate Solutions

REFERENCE CASE

Electricity

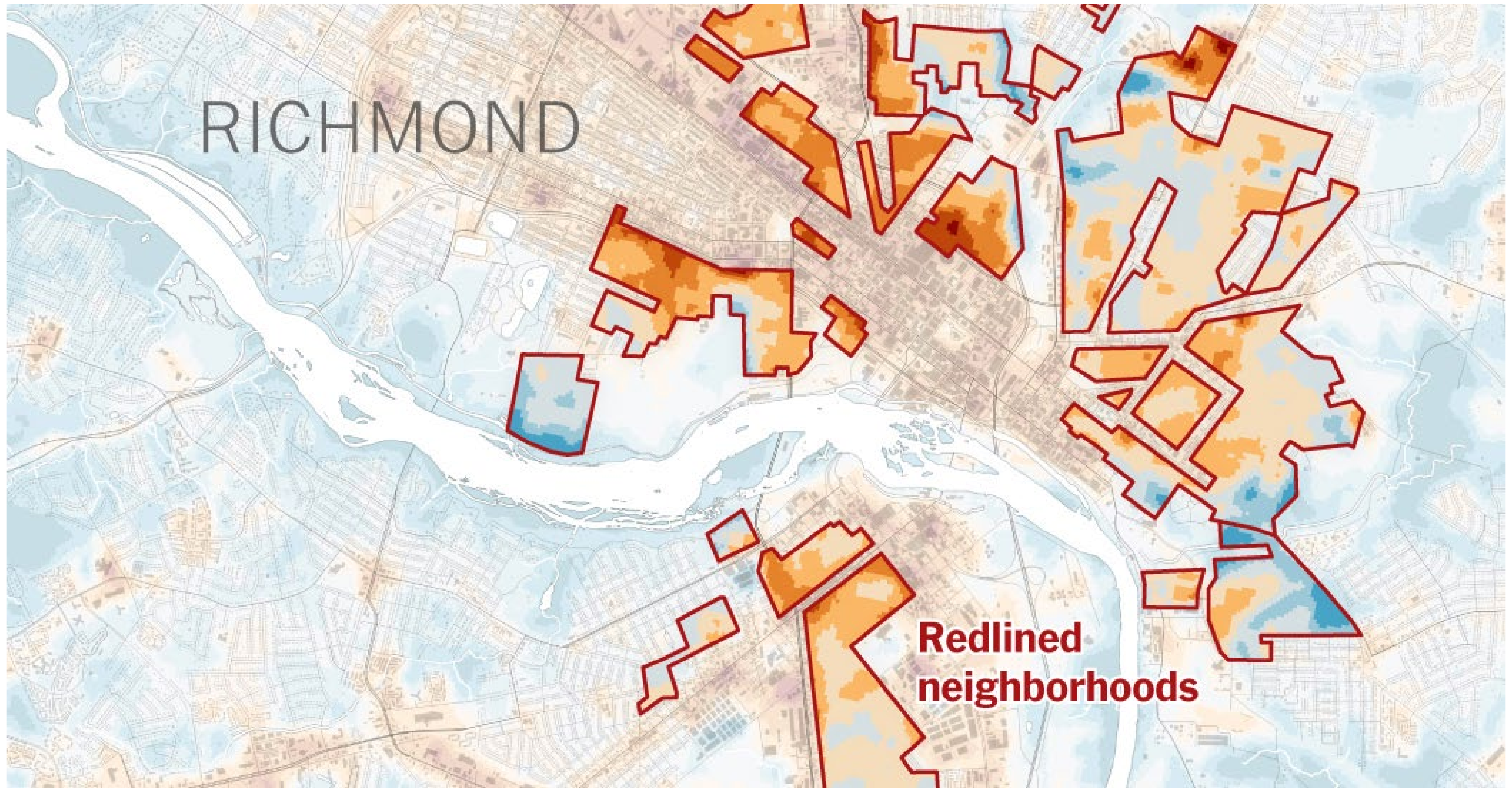
We need to have a clean grid. Washington passed the 100% clean electricity law (2019's Clean Energy Transformation Act), but Oregon does not have a similar law in place. We cannot meet our decarbonization goals for the Pacific Northwest until after Oregon passes a similar policy.



REFERENCE CASE

Health Benefits by Community Type

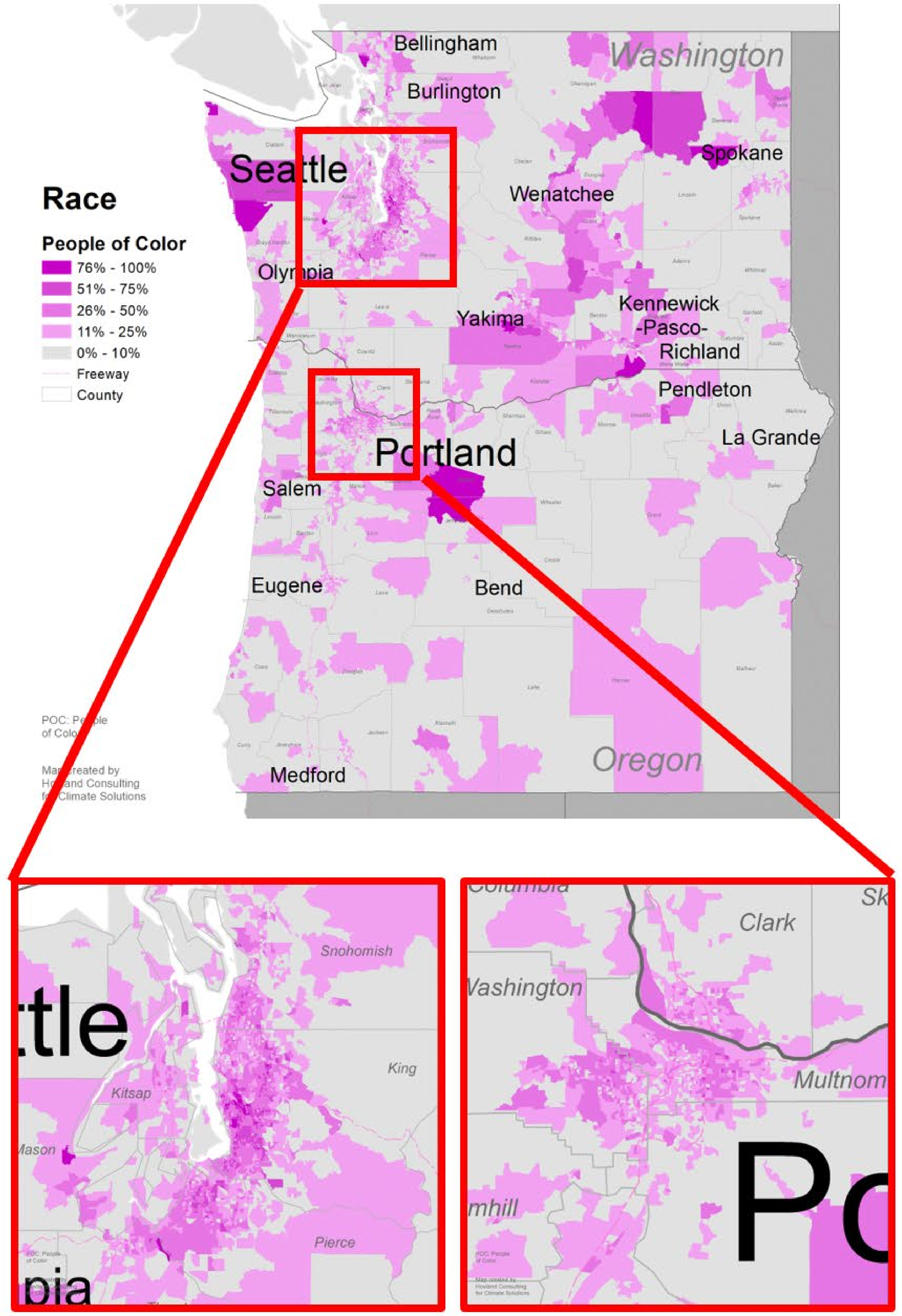
We do not experience harmful air pollution equally—a result of historic racist policies and practices like redlining, urban renewal districts, abuse of eminent domain, and inner-city highway construction, where racist policies have restricted and forced communities of color to move into concentrated, 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.

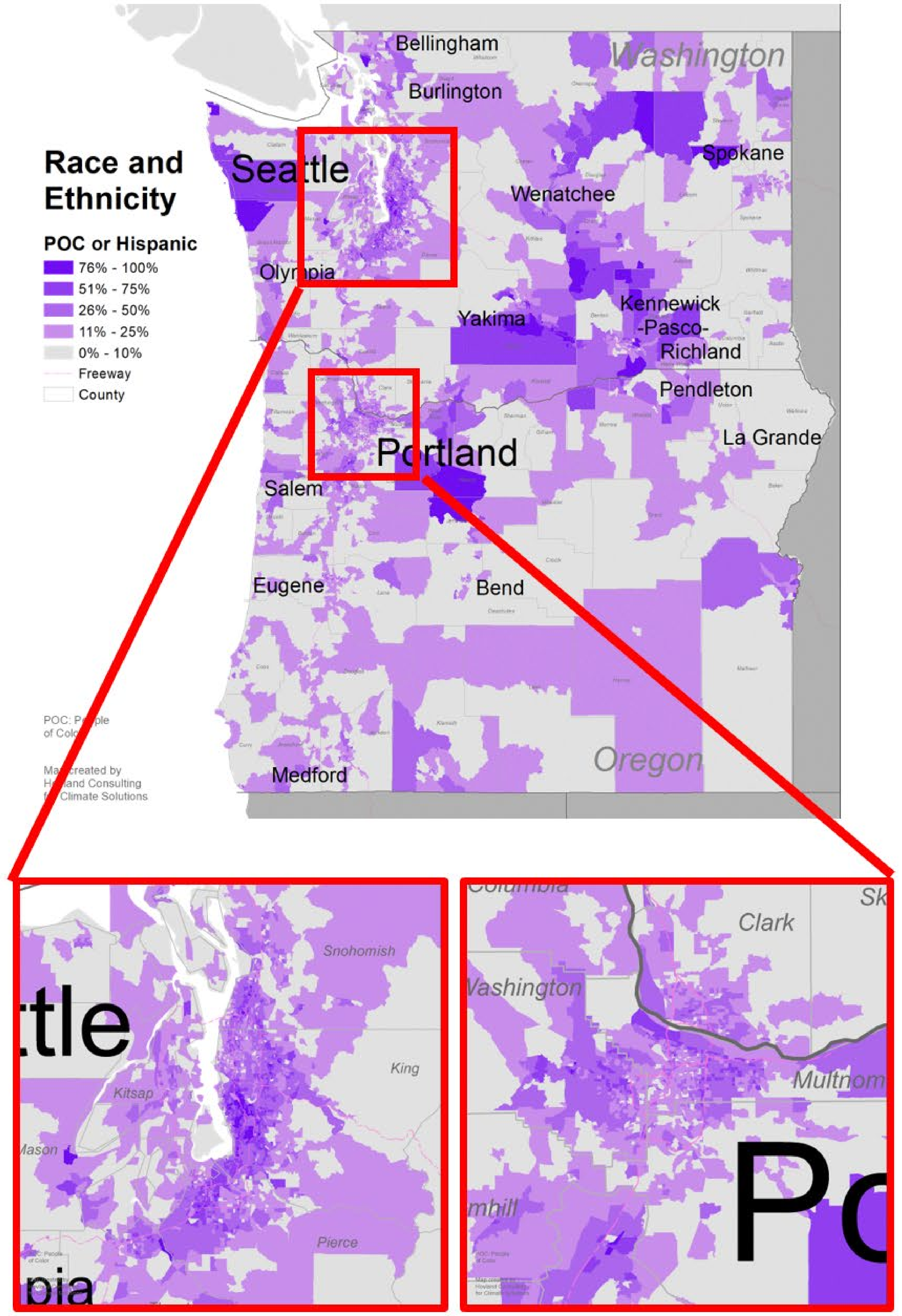


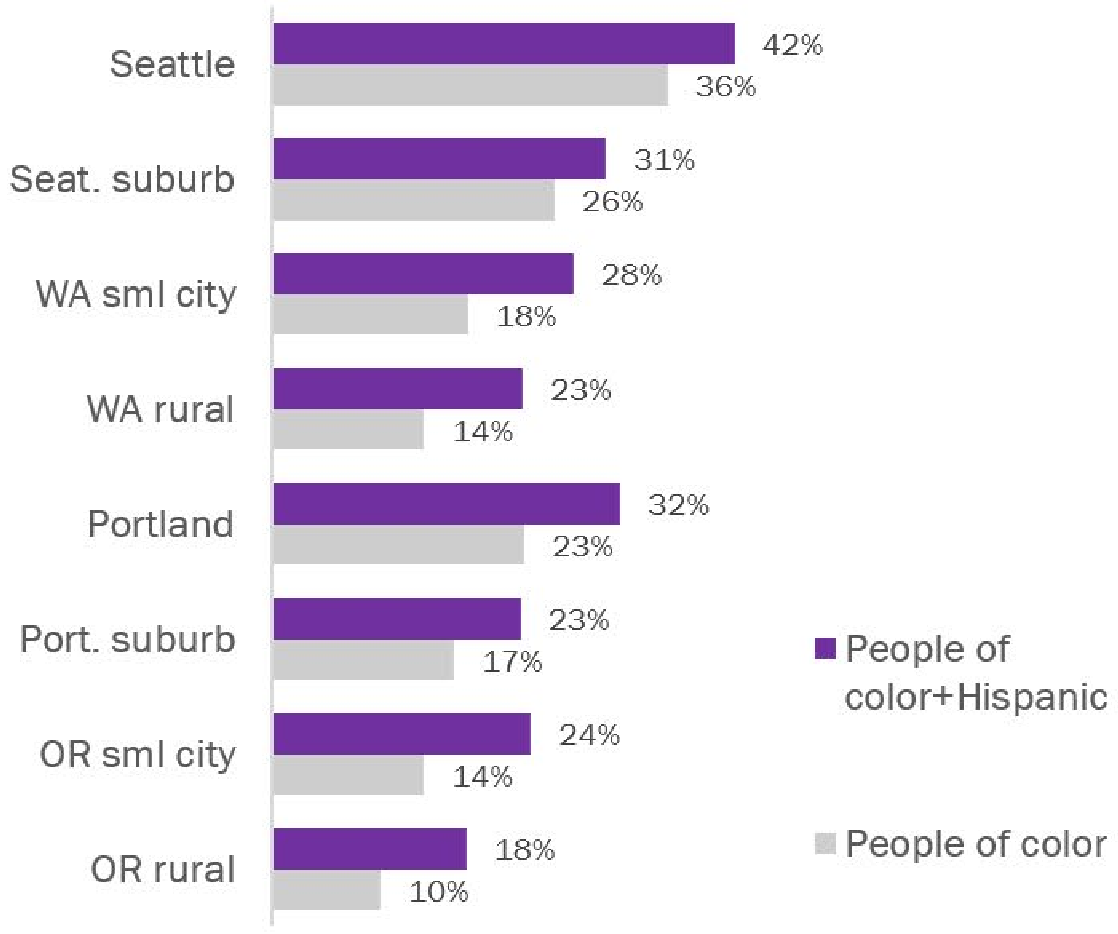
PC: NYTIMES

REFERENCE CASE

People of Color & People of Color + Hispanic

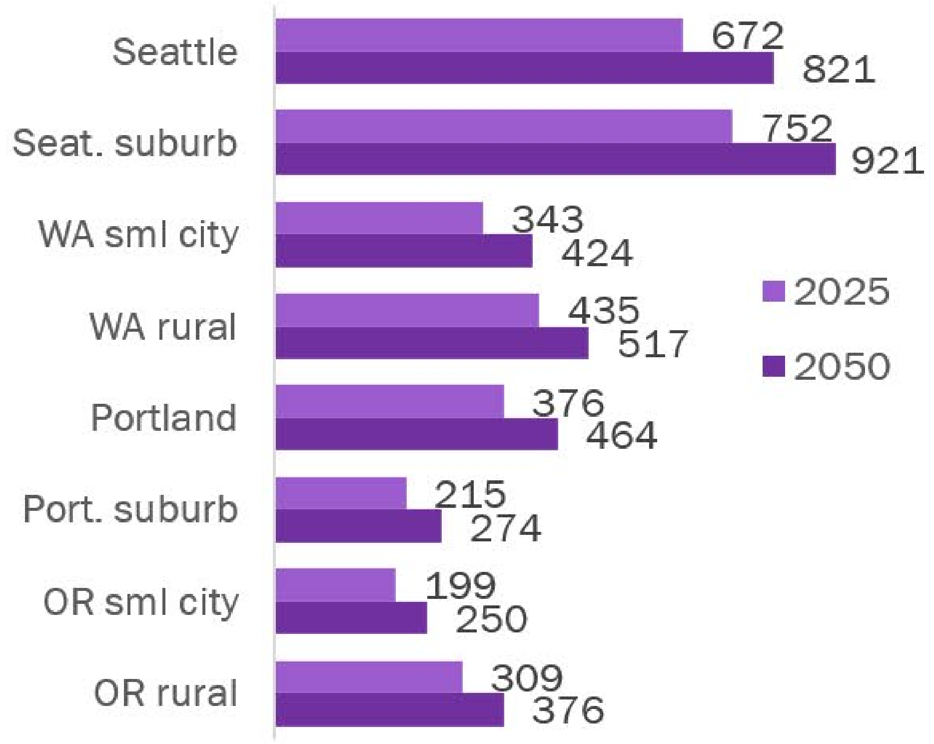






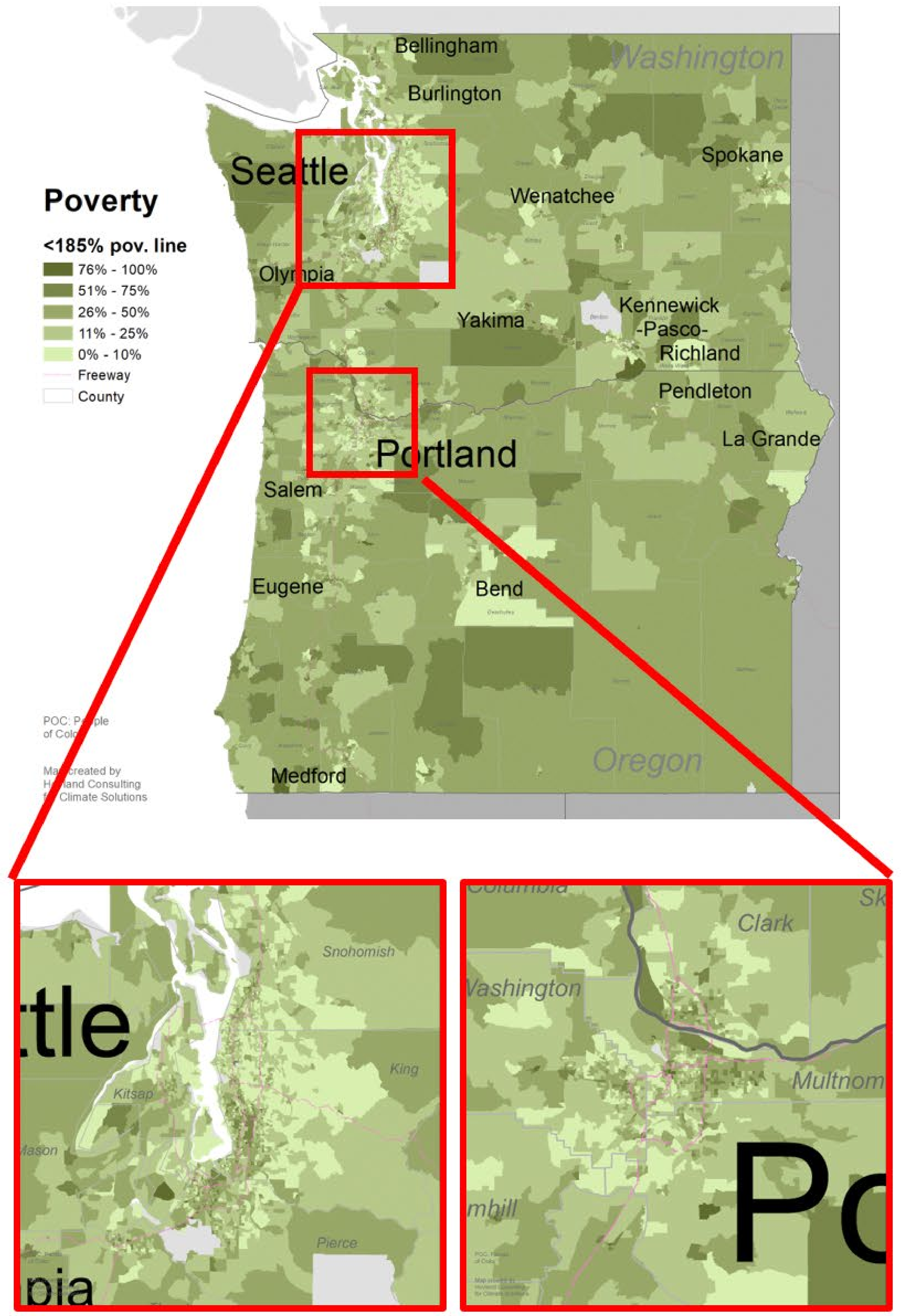
25-30% POC

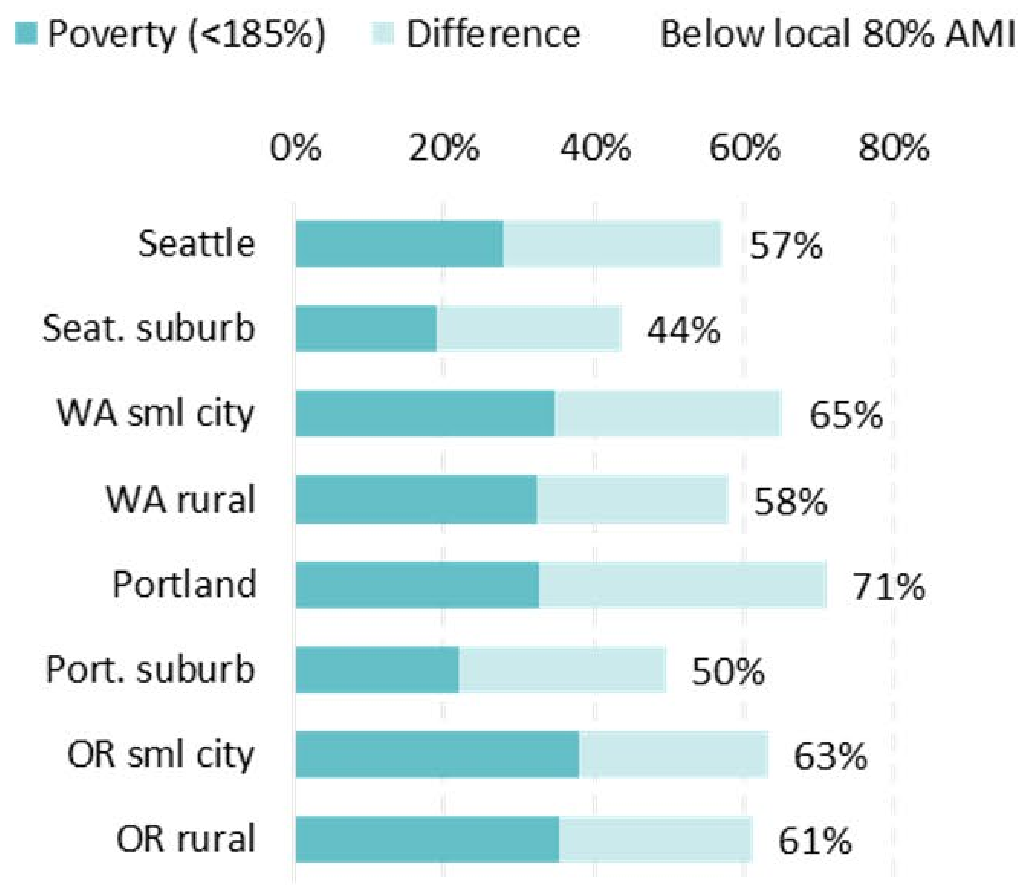
k people of color + Hispanic

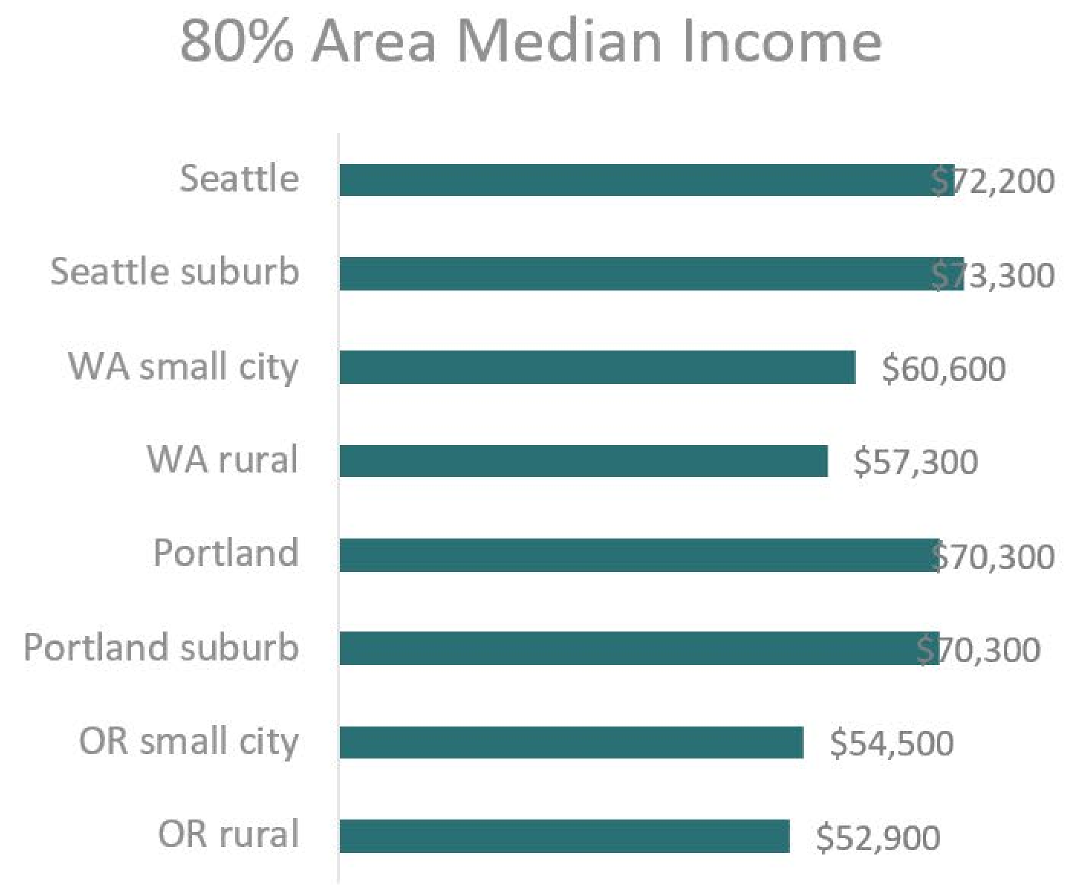


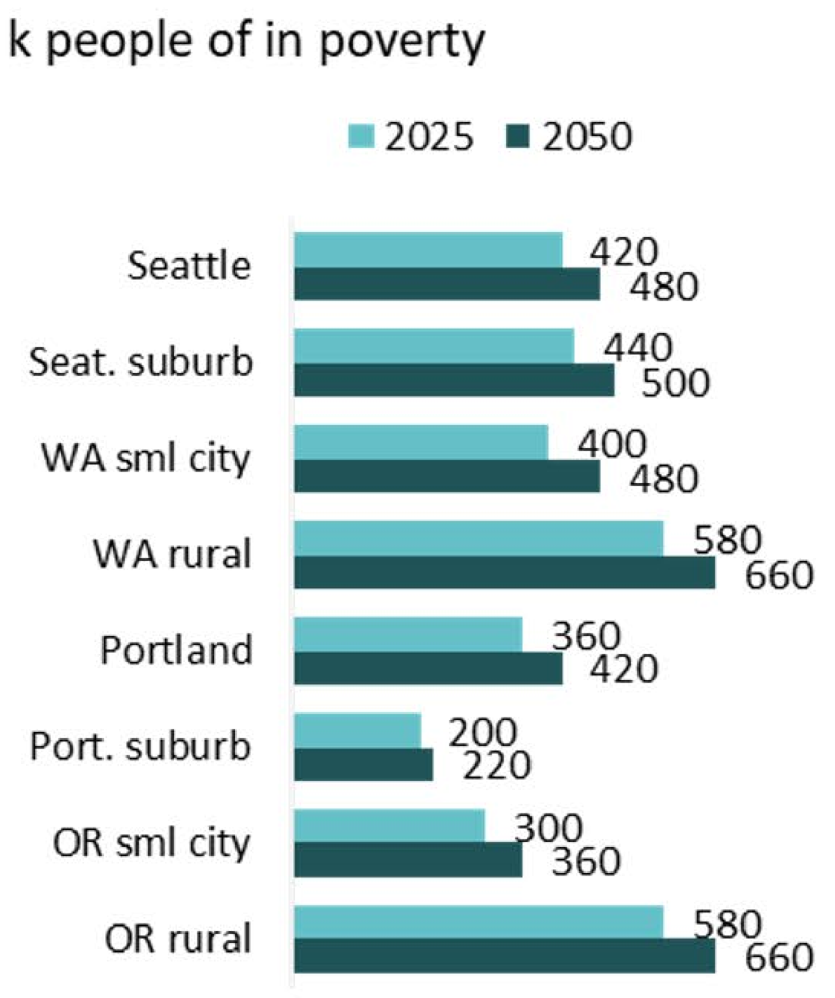
REFERENCE CASE

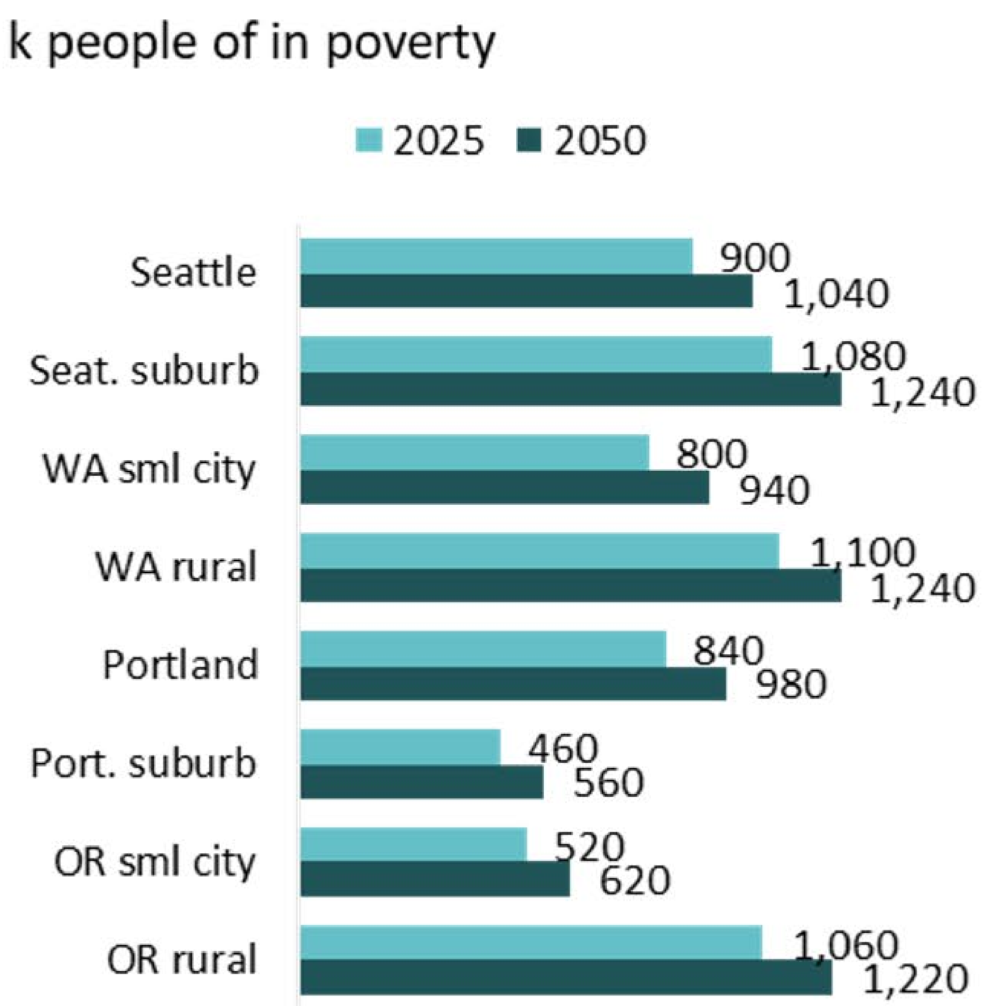
Below 185% Poverty Level











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

REFERENCE CASE

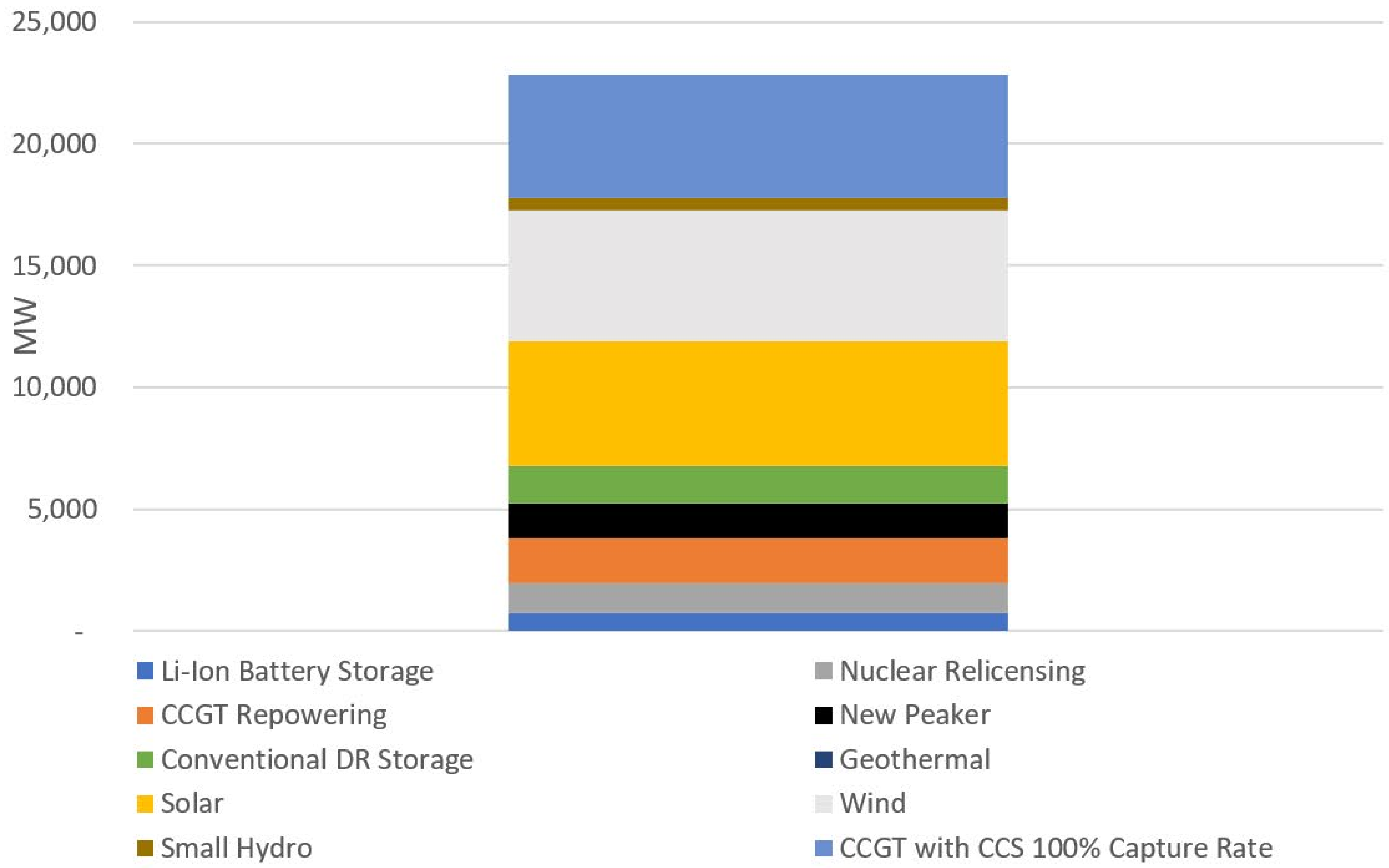
Electricity

ELECTRICITY BY THE NUMBERS

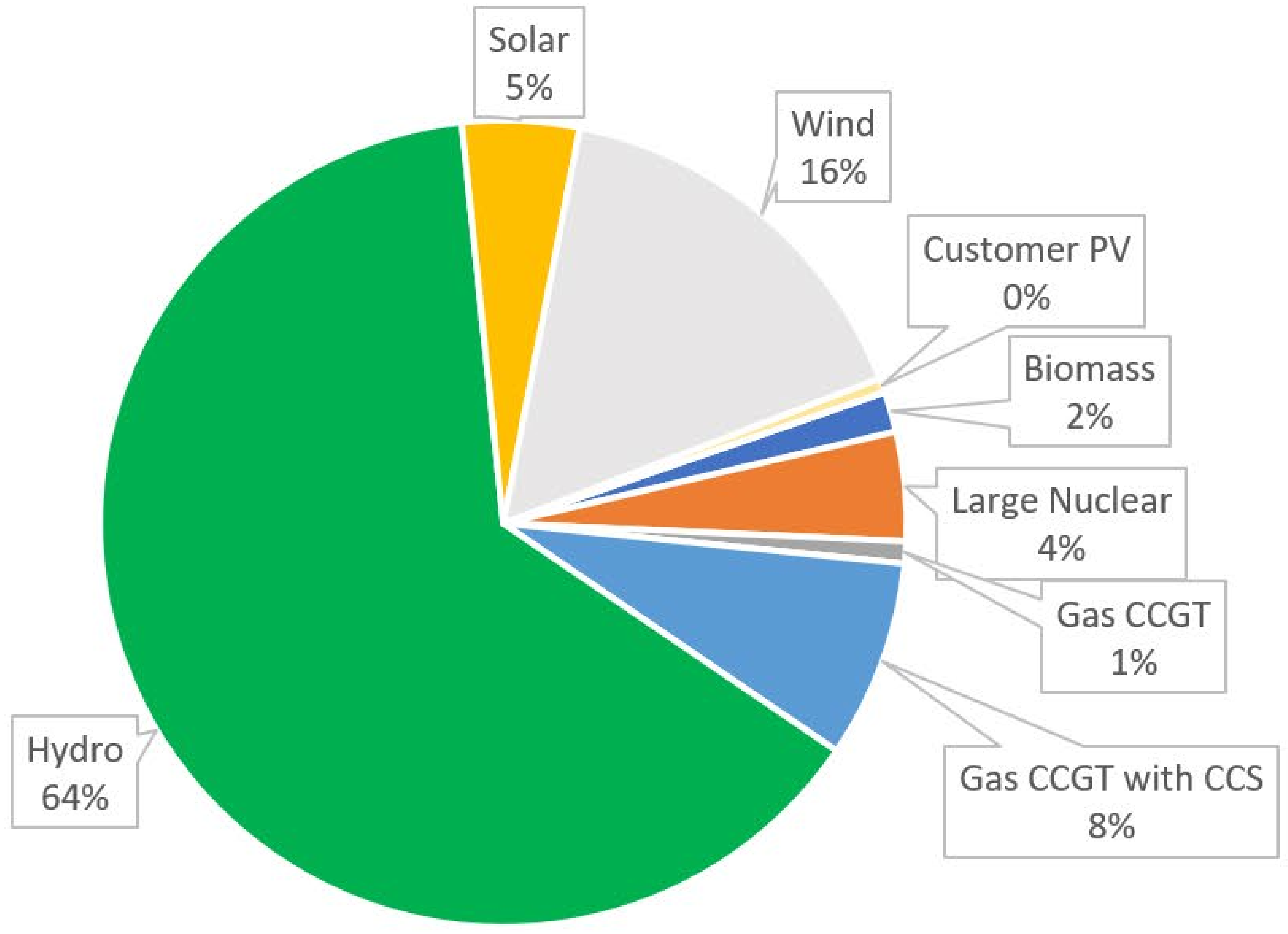
System cost	$18.89 B

Total load (TWh) 198 Peak Capacity (GW) 36

Resource Builds 2050



Energy Mix



THE SCENARIOS

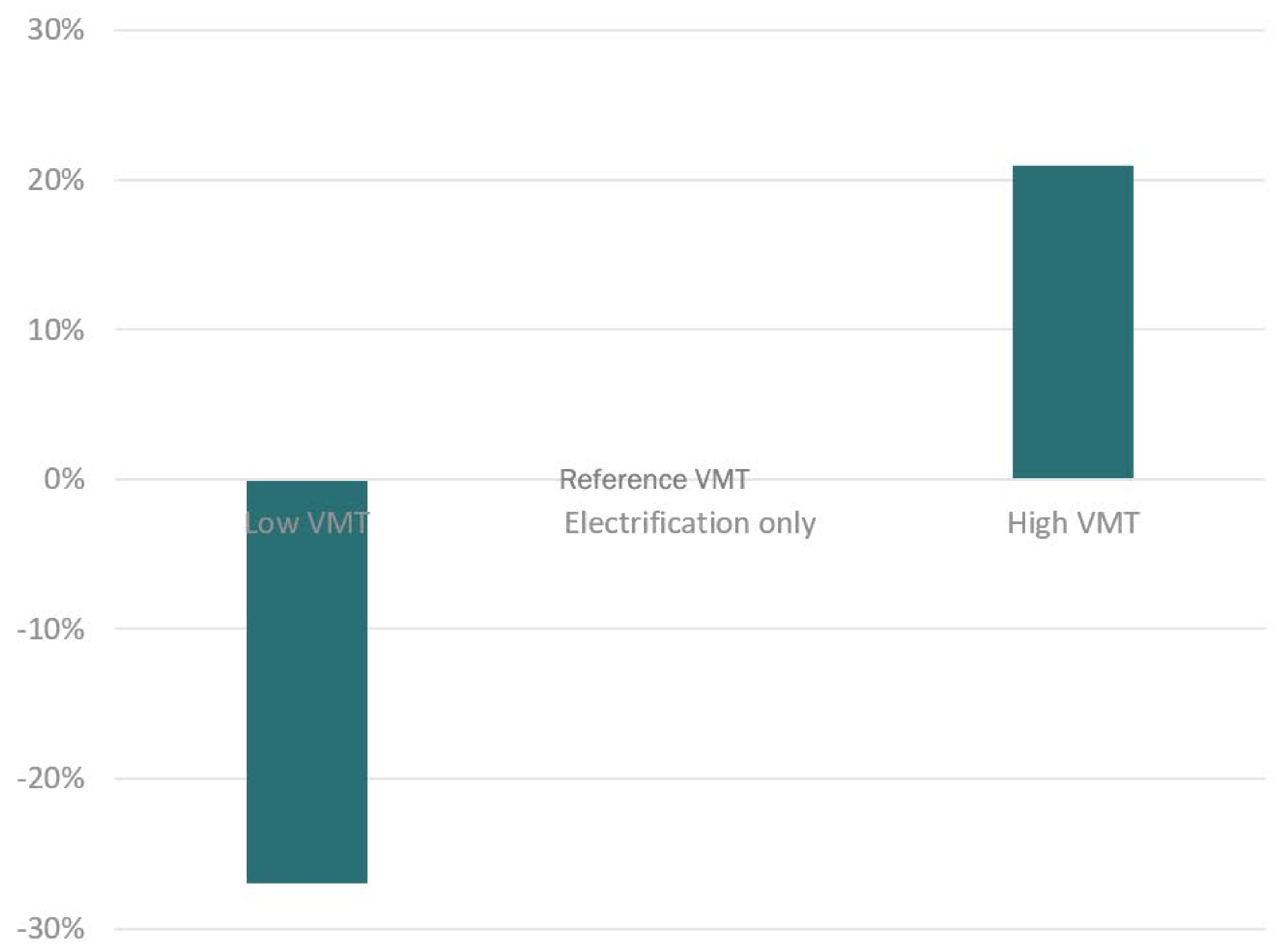
We know we need to transition away from fossil fuels, but now do we get there? Which path is ideal?

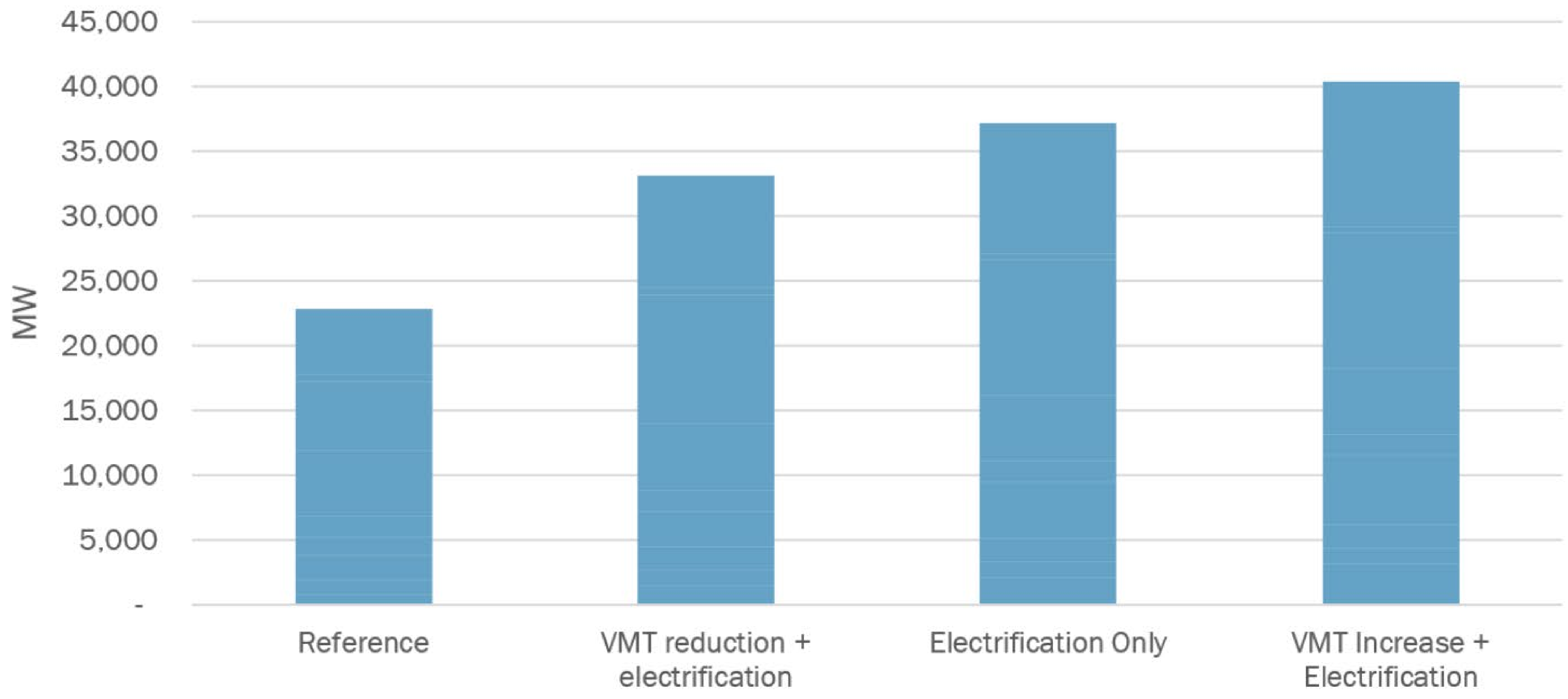
SCENARIOS

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.

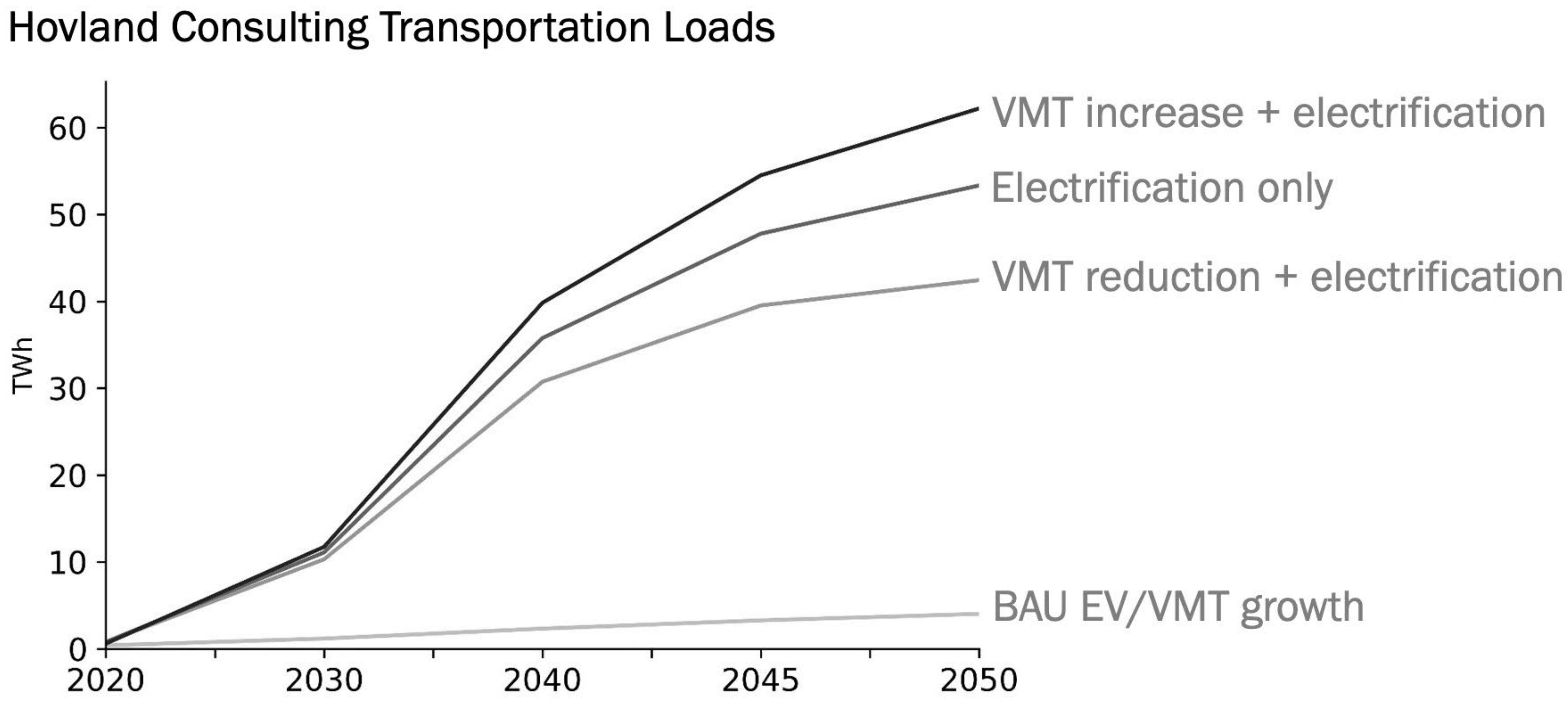
Each scenario leads to different electricity needs.





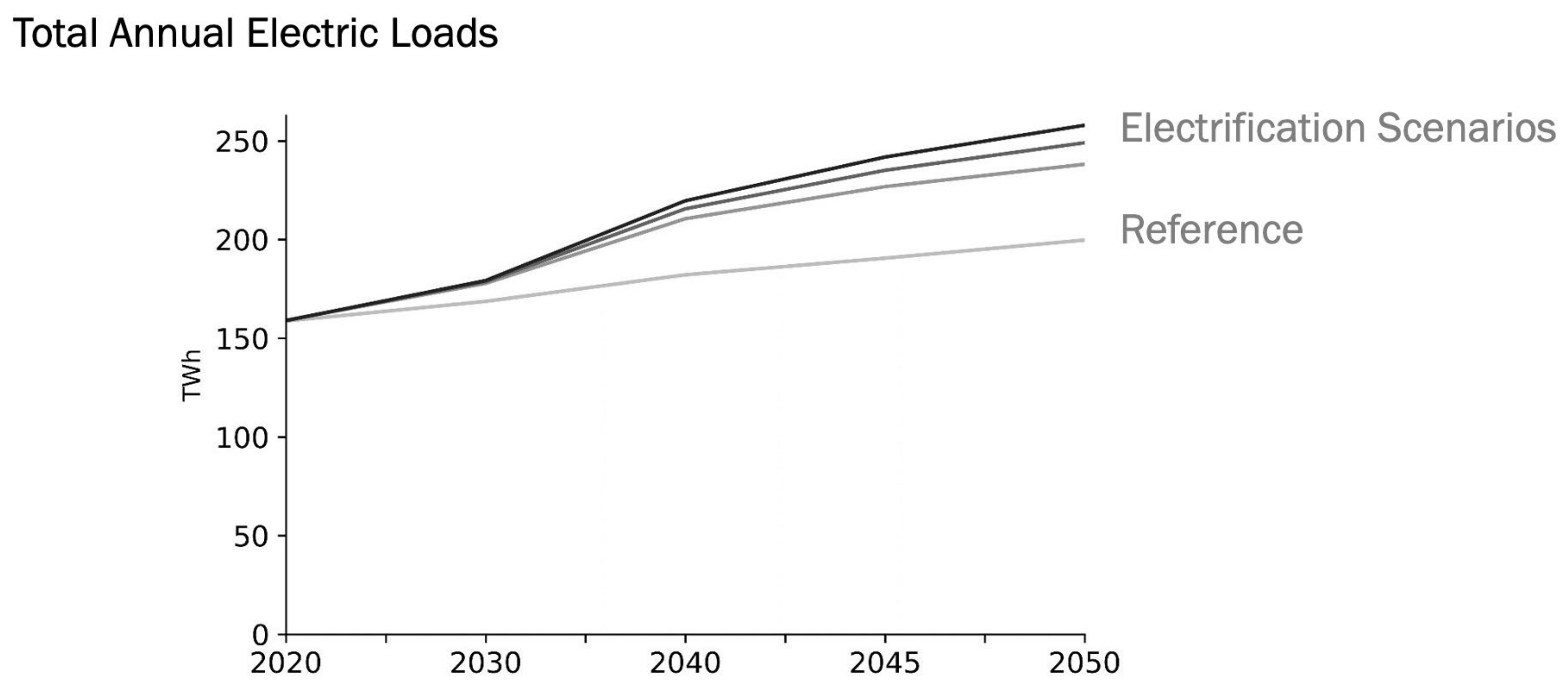
Electrification: Load scenarios

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

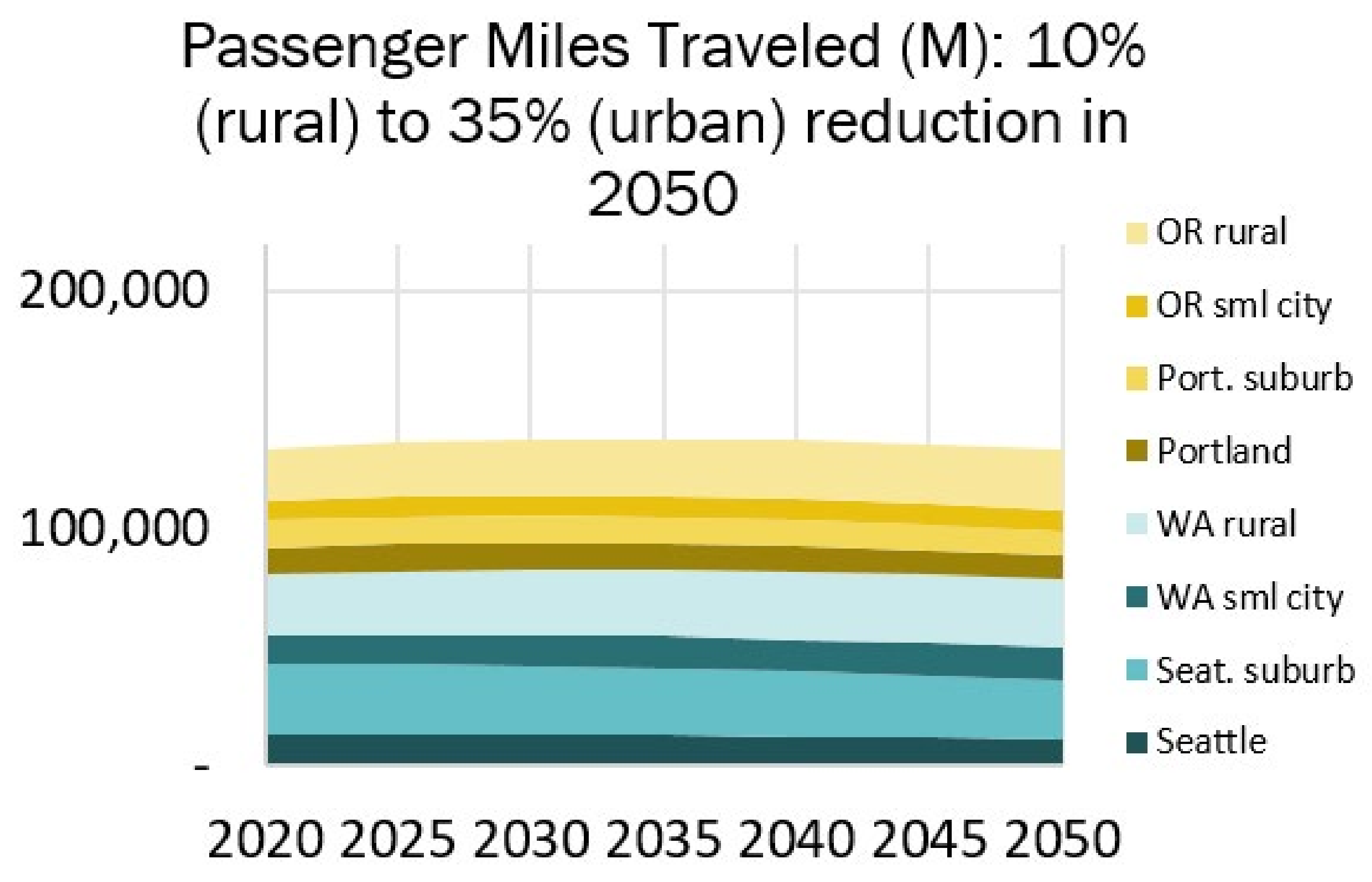
Vehicle Miles Traveled Reduced

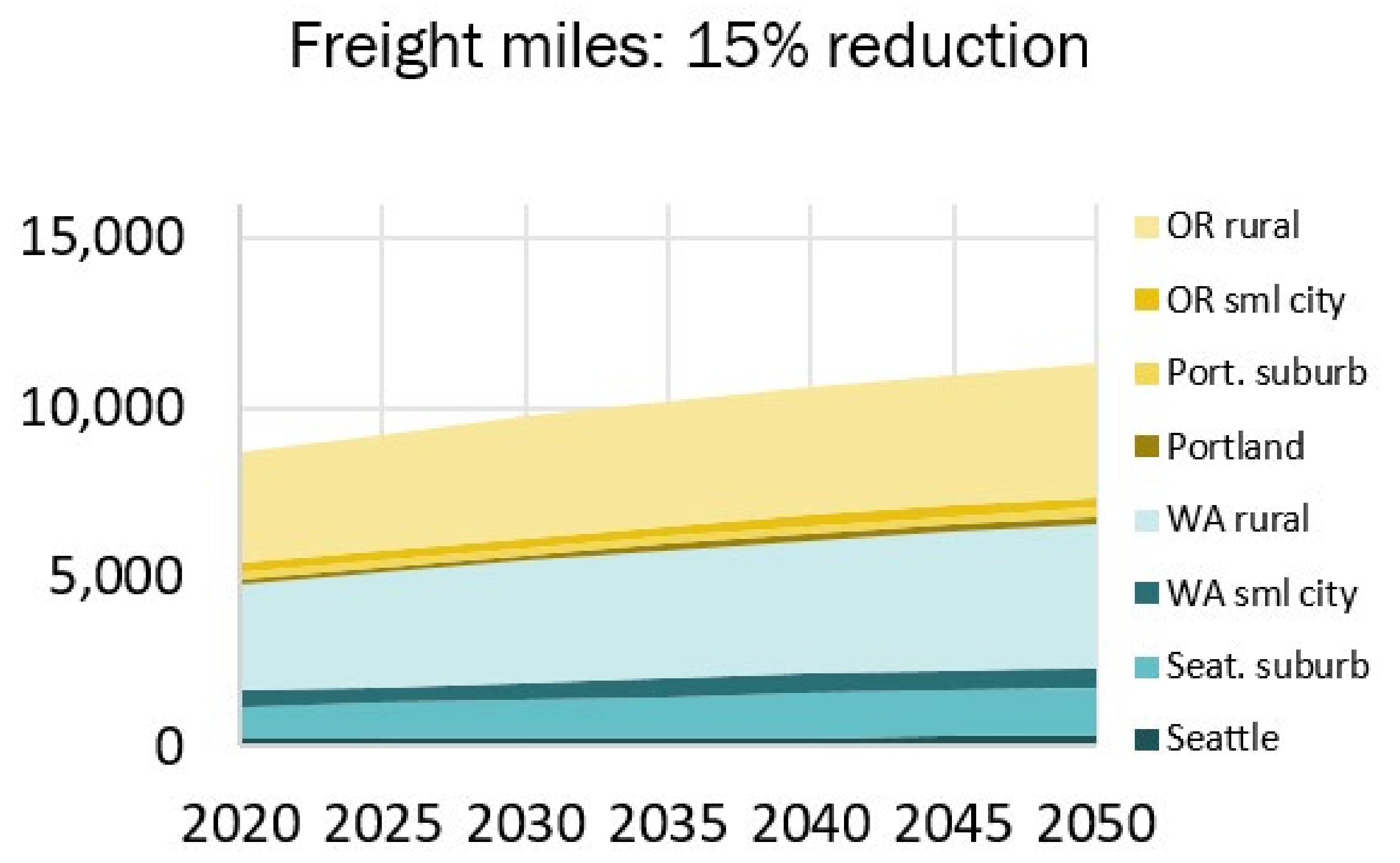
+ Electrification

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.

Scenario 1 relative to business as usual.

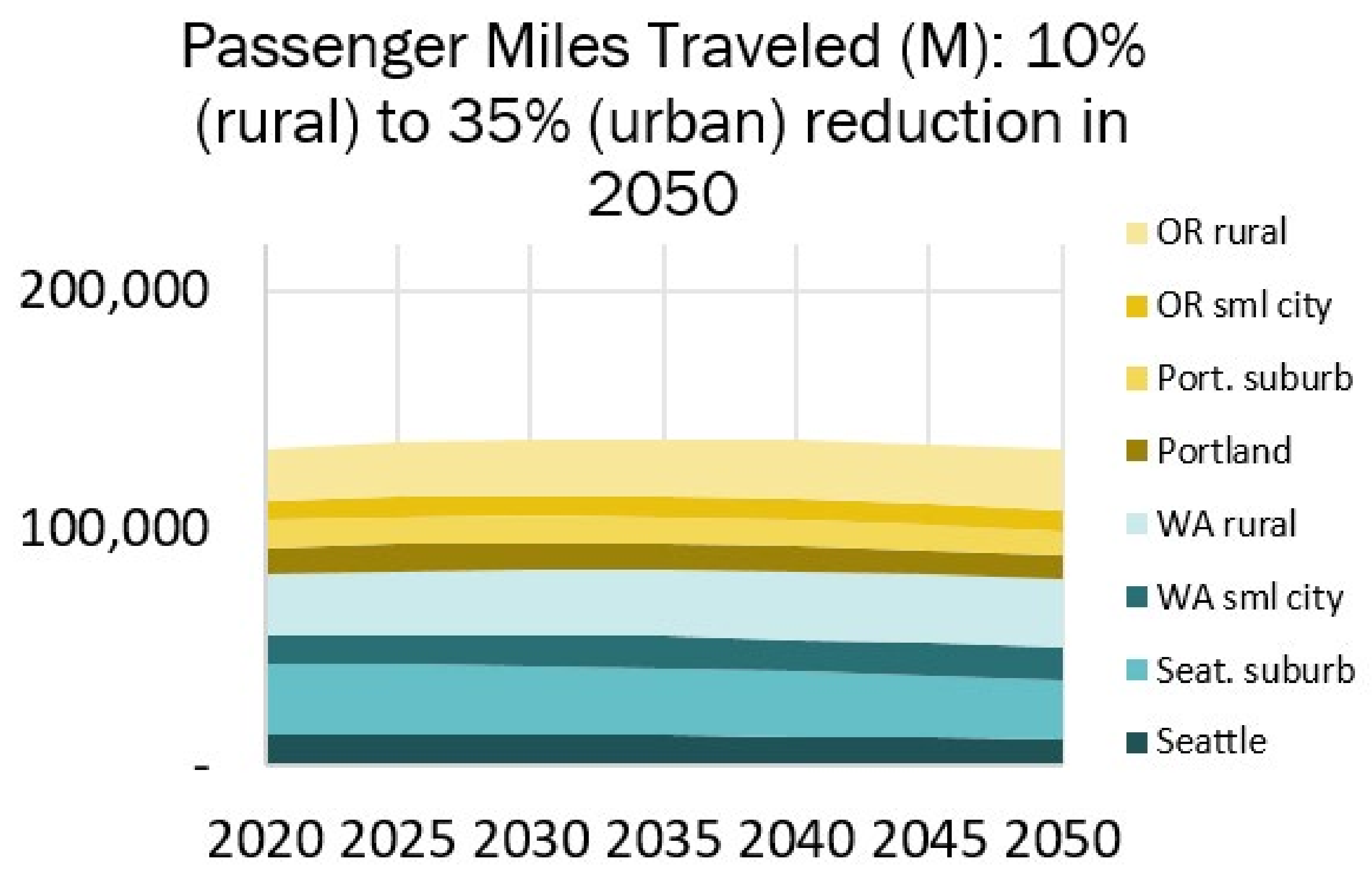


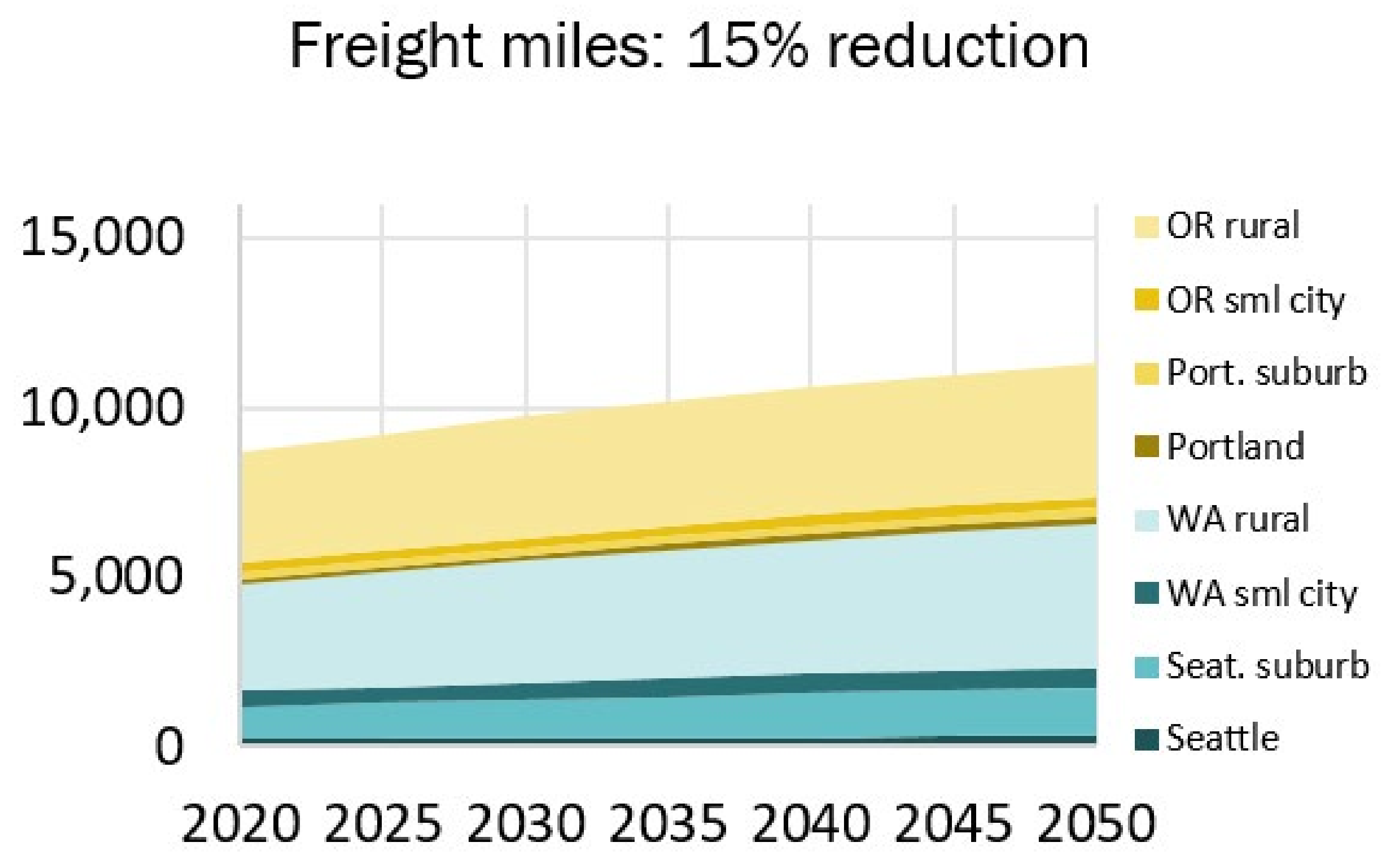


PLUS WE CAN INCREASE SAFETY AND REDUCE COSTS.

Employing both decreased VMT and electrifying leads to ***greater total carbon reductions***. This scenario takes ample policy change and planning.

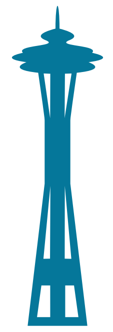
Scenario 1 relative to business as usual.



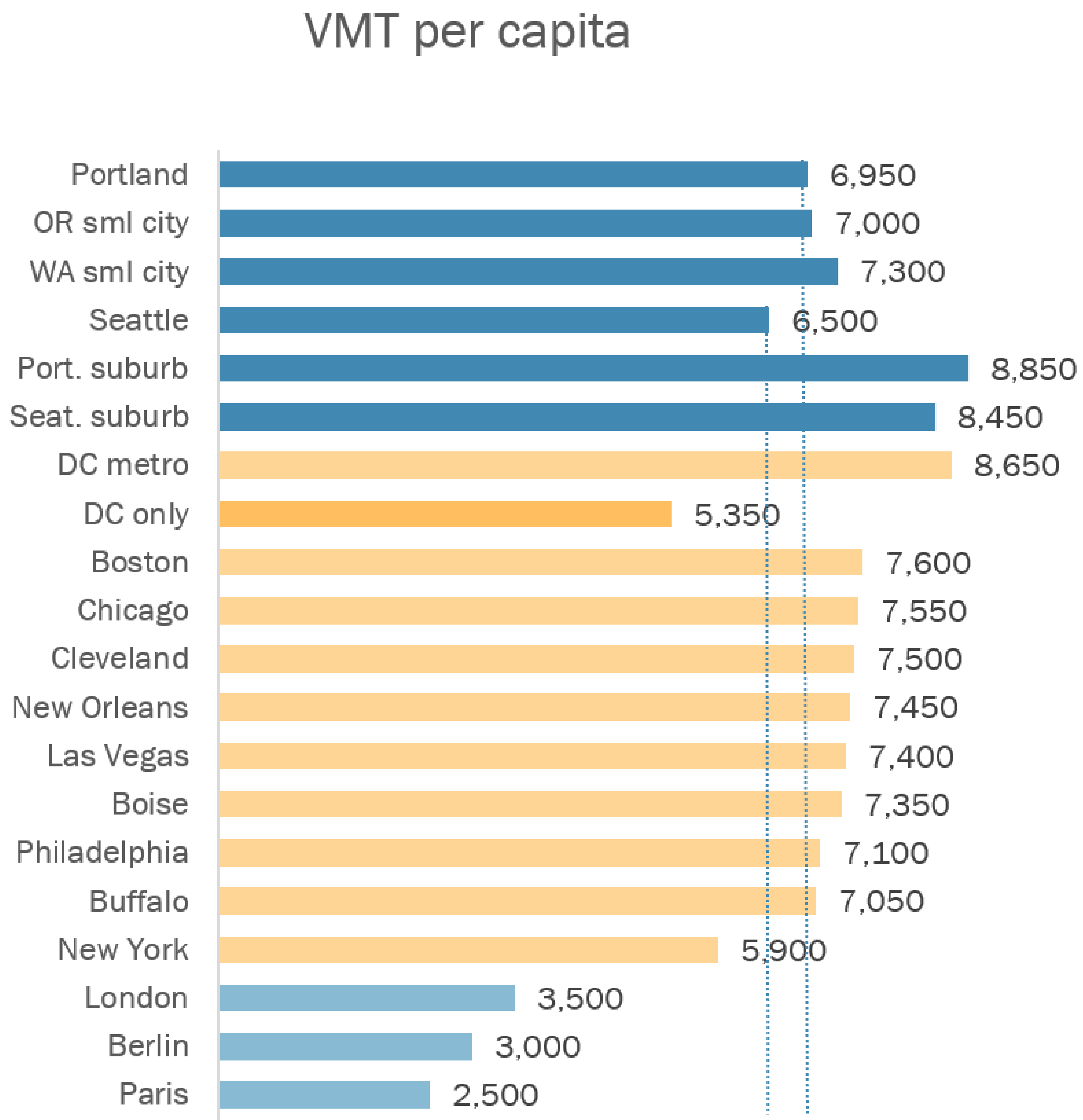


SCENARIO 1: ⬇ VMT + ⚡

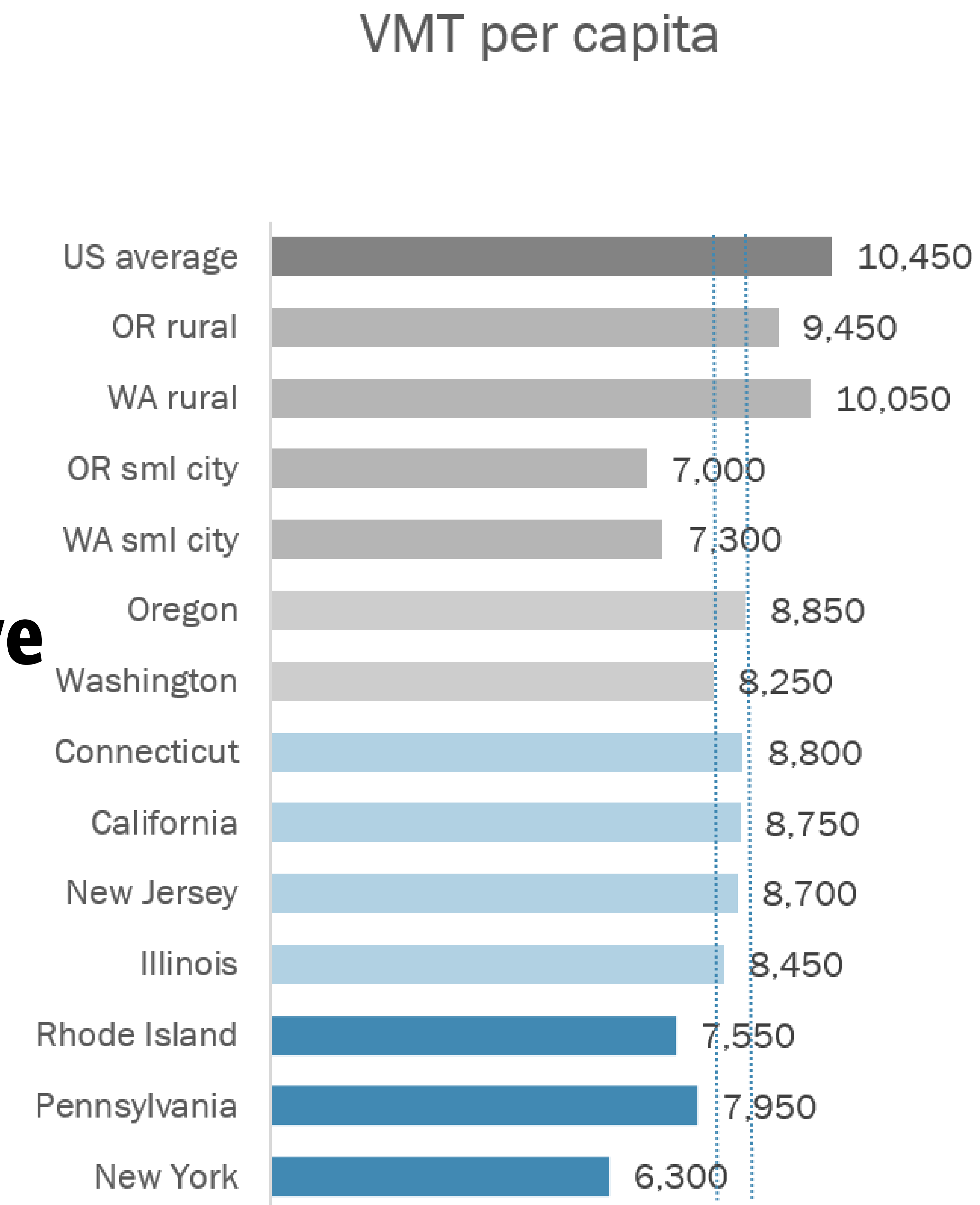
Comparison: Vehicle Miles Traveled



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.

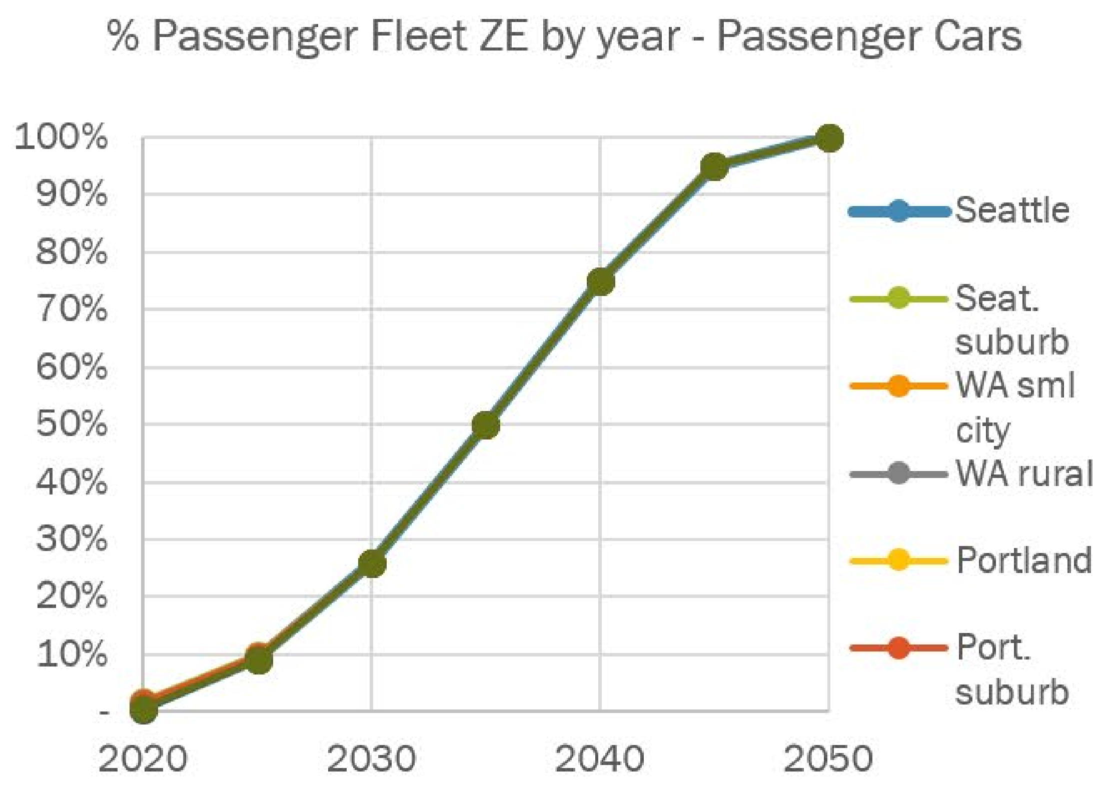
	Passenger Miles Traveled Reduction	Equivalent Personal Vehicle Miles Traveled Reduction (with bus, walk, micromobility)	Equivalent to
Urban	35%	47%	London (lower than NYC)
Suburban	35%	39%	Washington DC & London average
Small city	15%	20%	New York state
Rural	10%	10%	States like CA, CT, NJ, IL

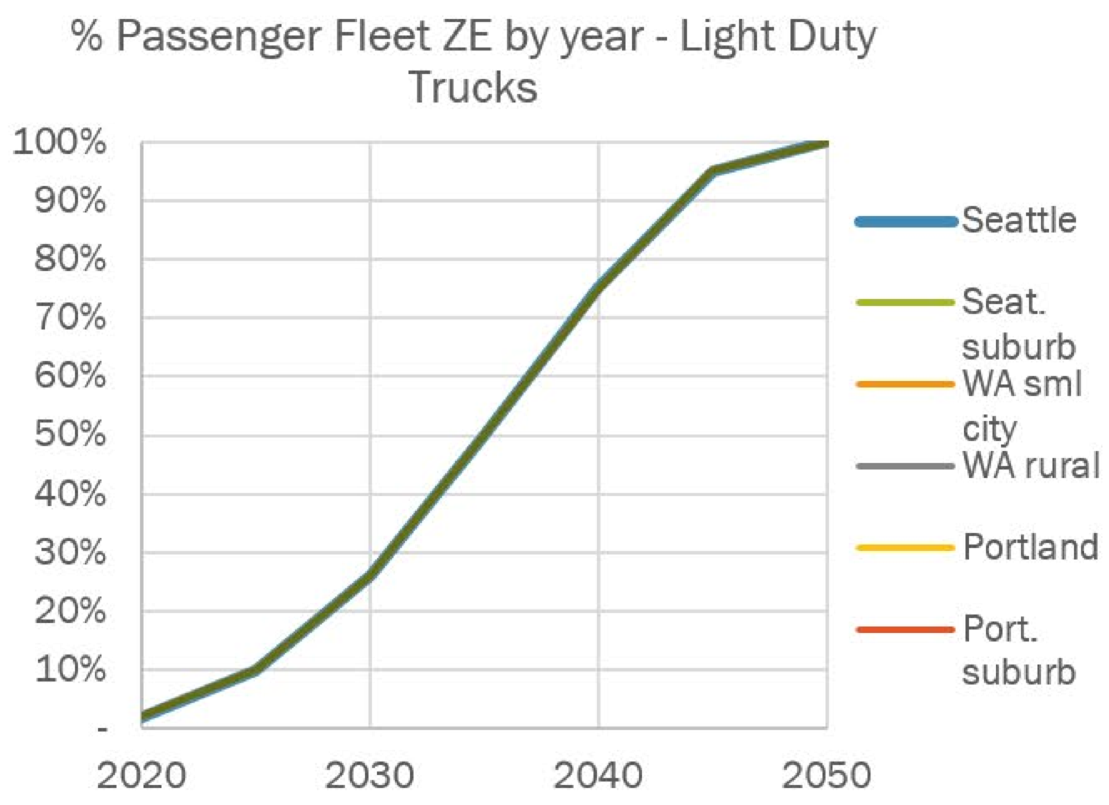
	Miles Traveled Reduction	References
Freight	15%	Other scenarios (EIA) have 8% reduction. This represents different economic growth scenarios.
State-wide	29% PMT reduction	27% VMT reduction (personal & freight)

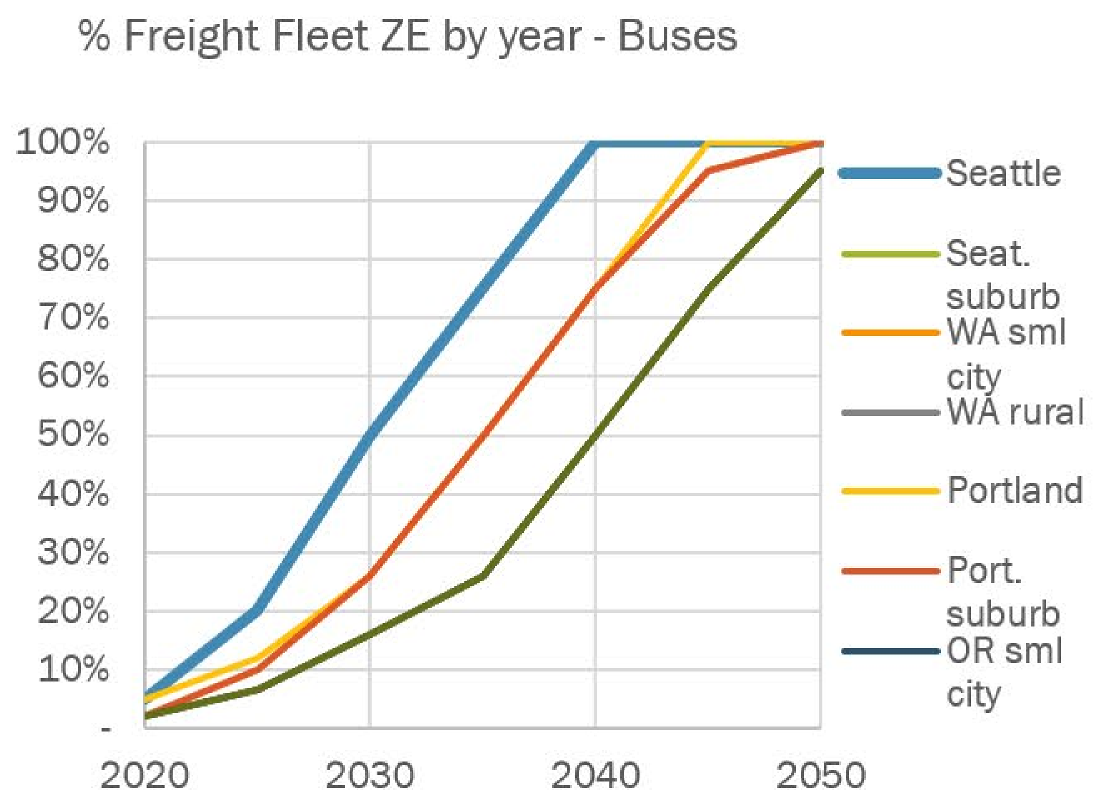
SCENARIO 1: ⬇VMT + ⚡

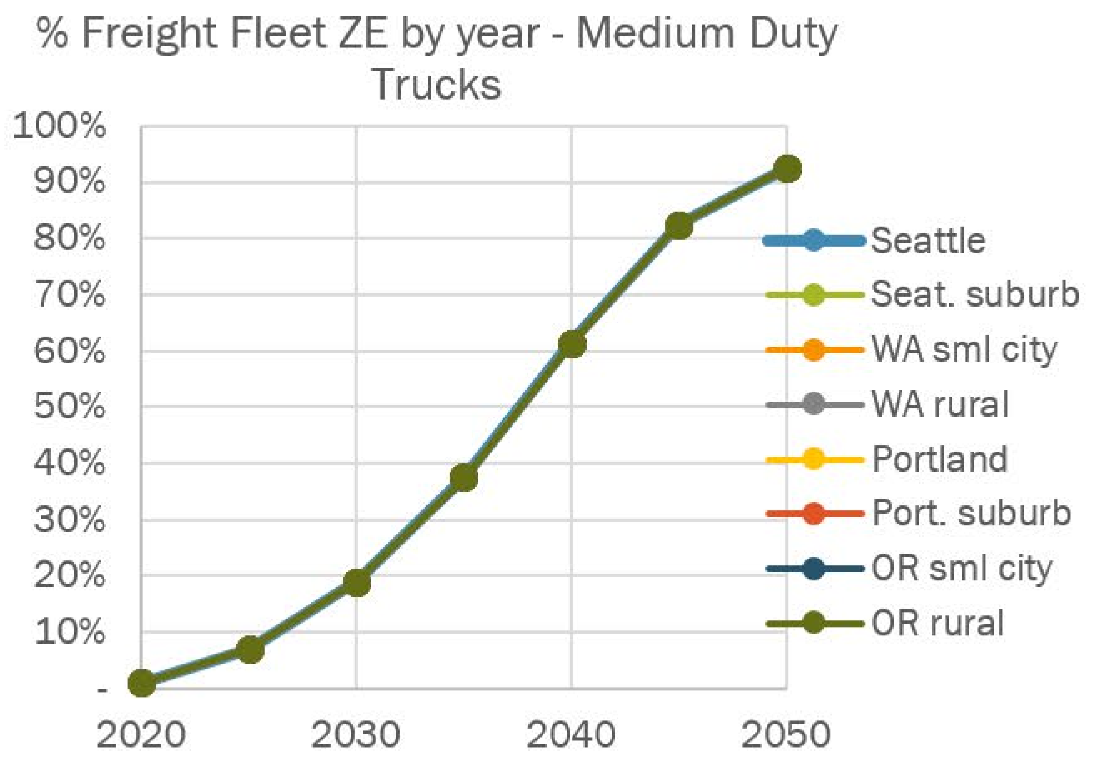
Near-100% Electrification

This scenario combines high electrification rates with reduced vehicle miles traveled.





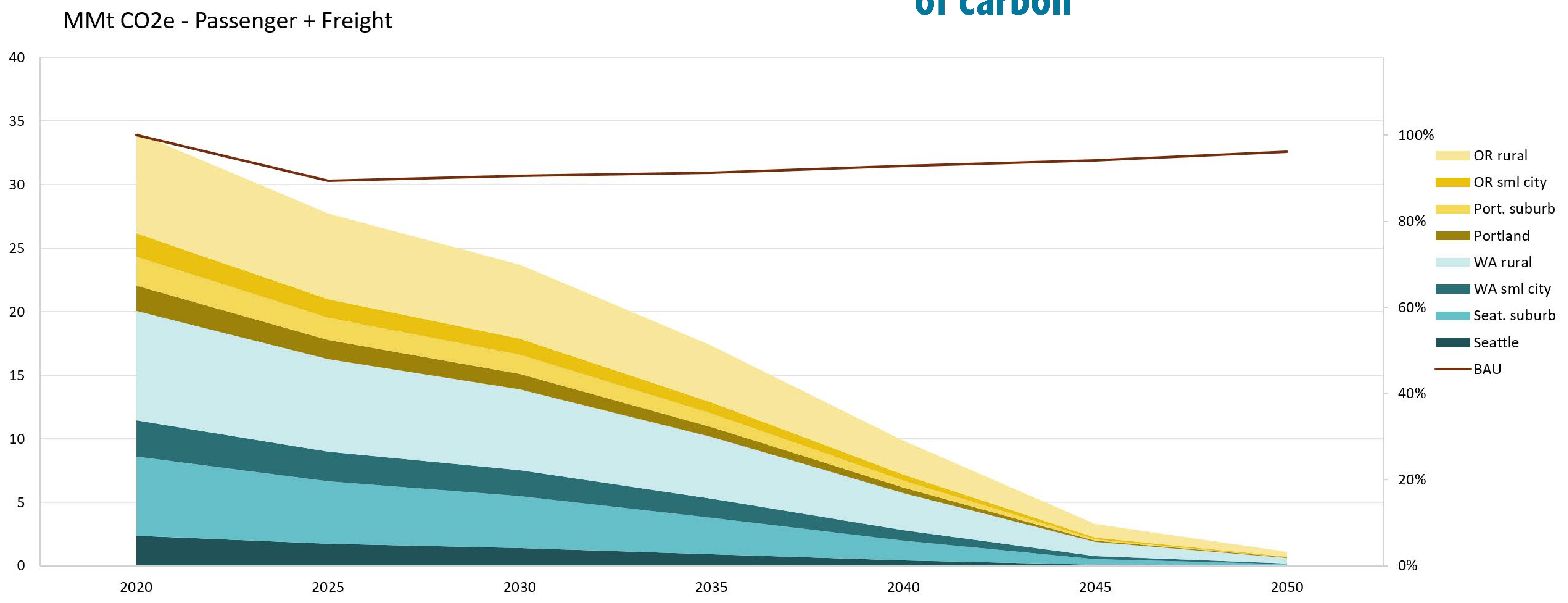




SCENARIO 1: ⬇ VMT + ⚡

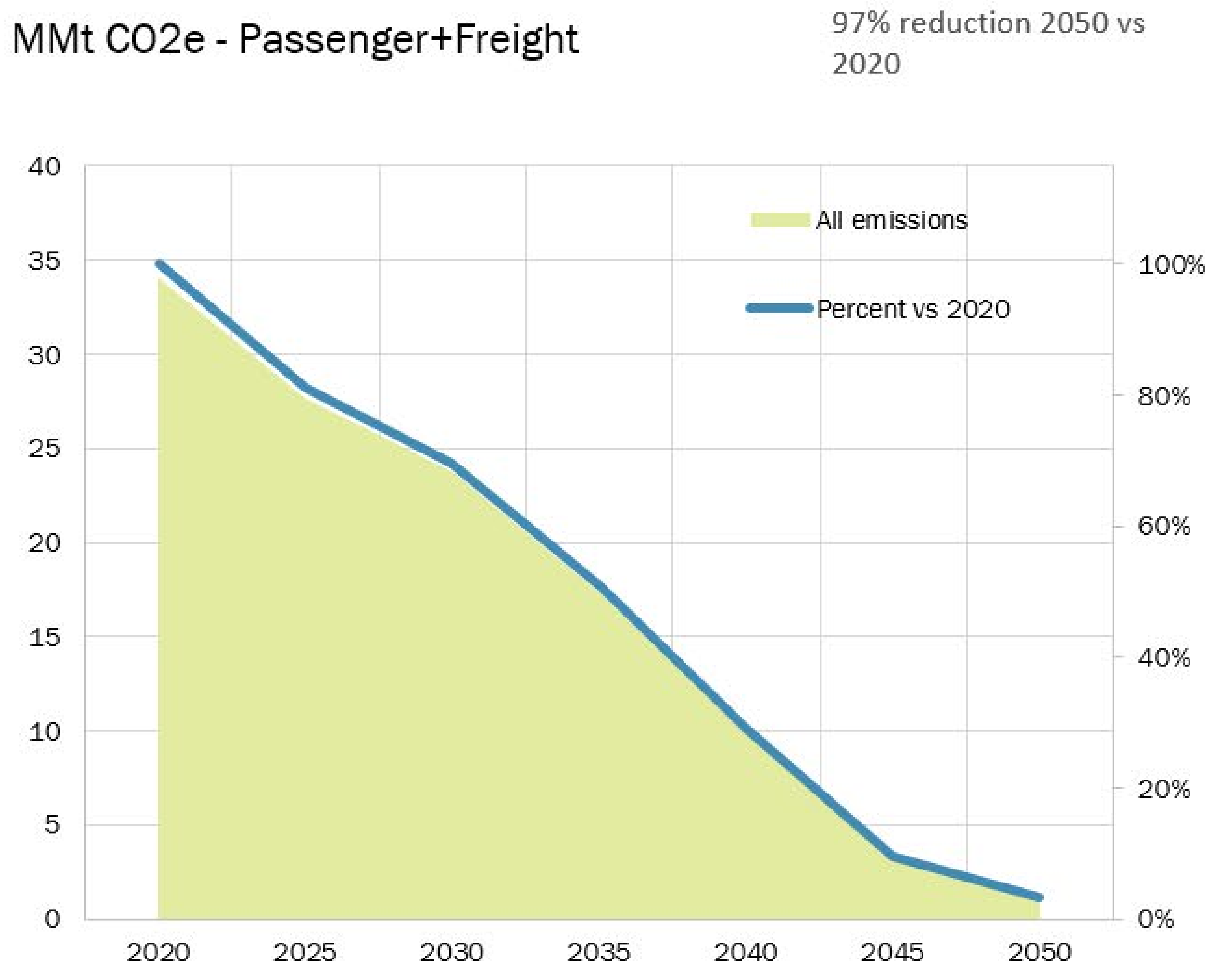
Greenhouse Gas Emissions

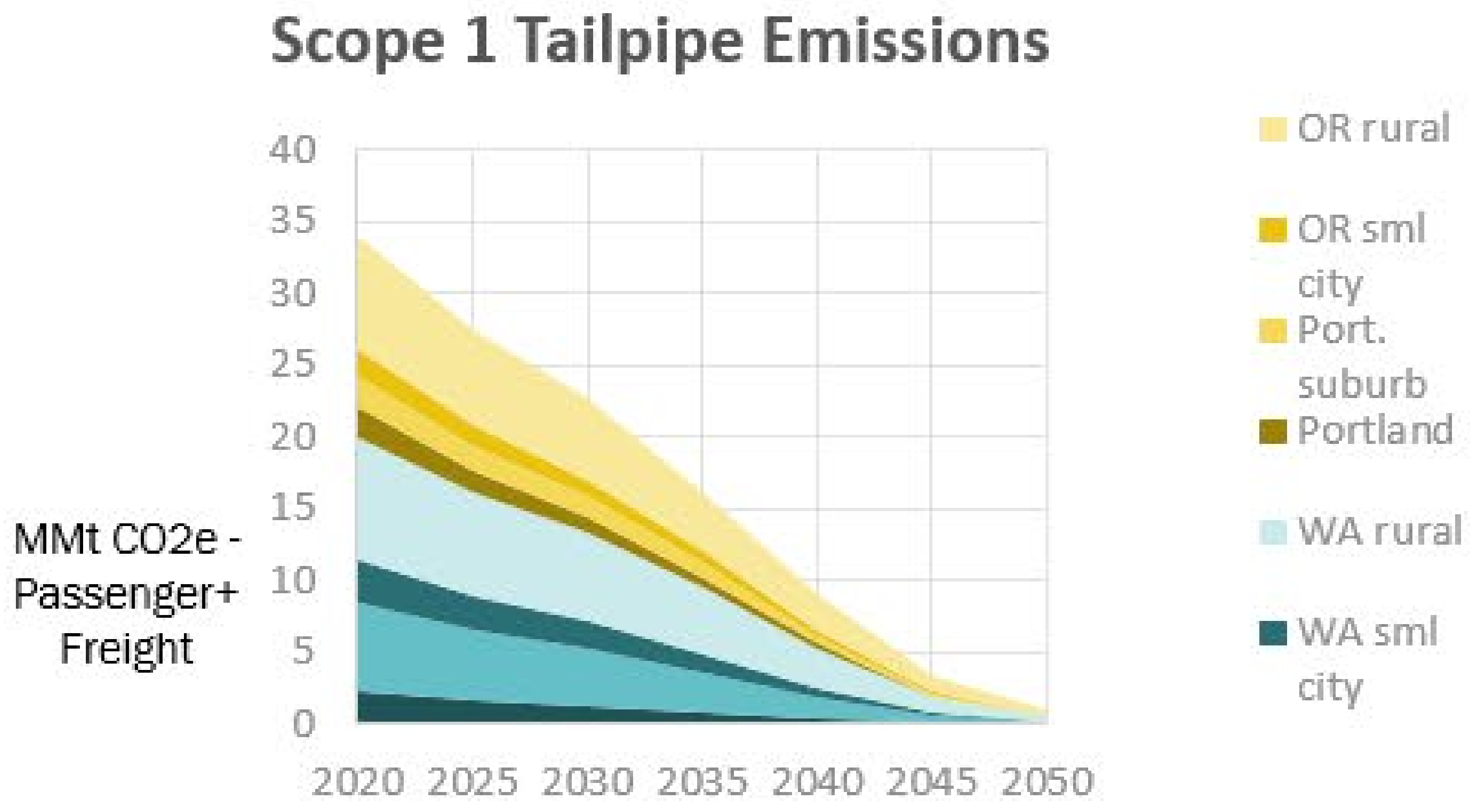
515 MMT total carbon emissions from 2020-2050, 475 MMT less than BAU = $41 billion less in social cost of carbon

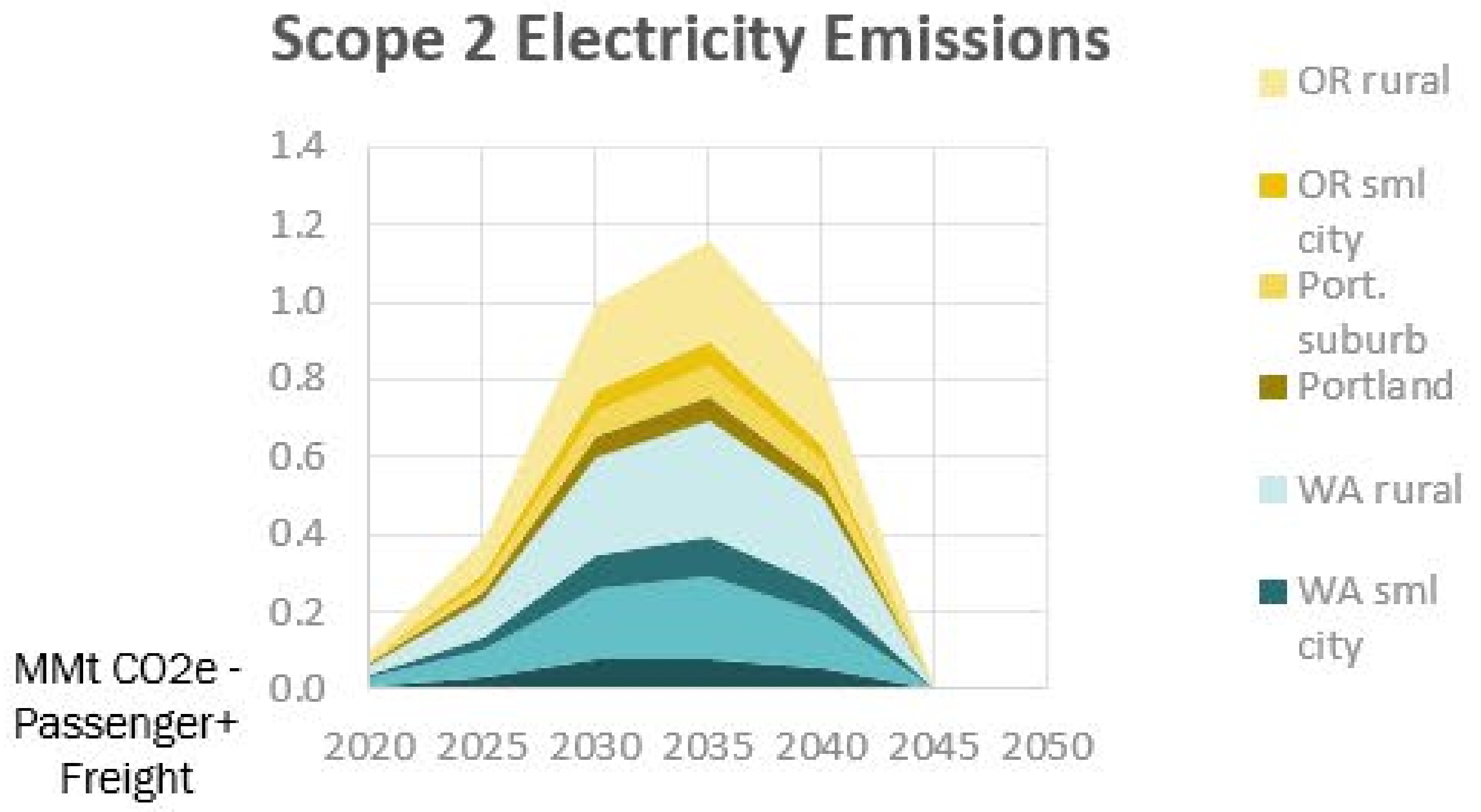


SCENARIO 1: ⬇ VMT + ⚡

Greenhouse Gas Emissions



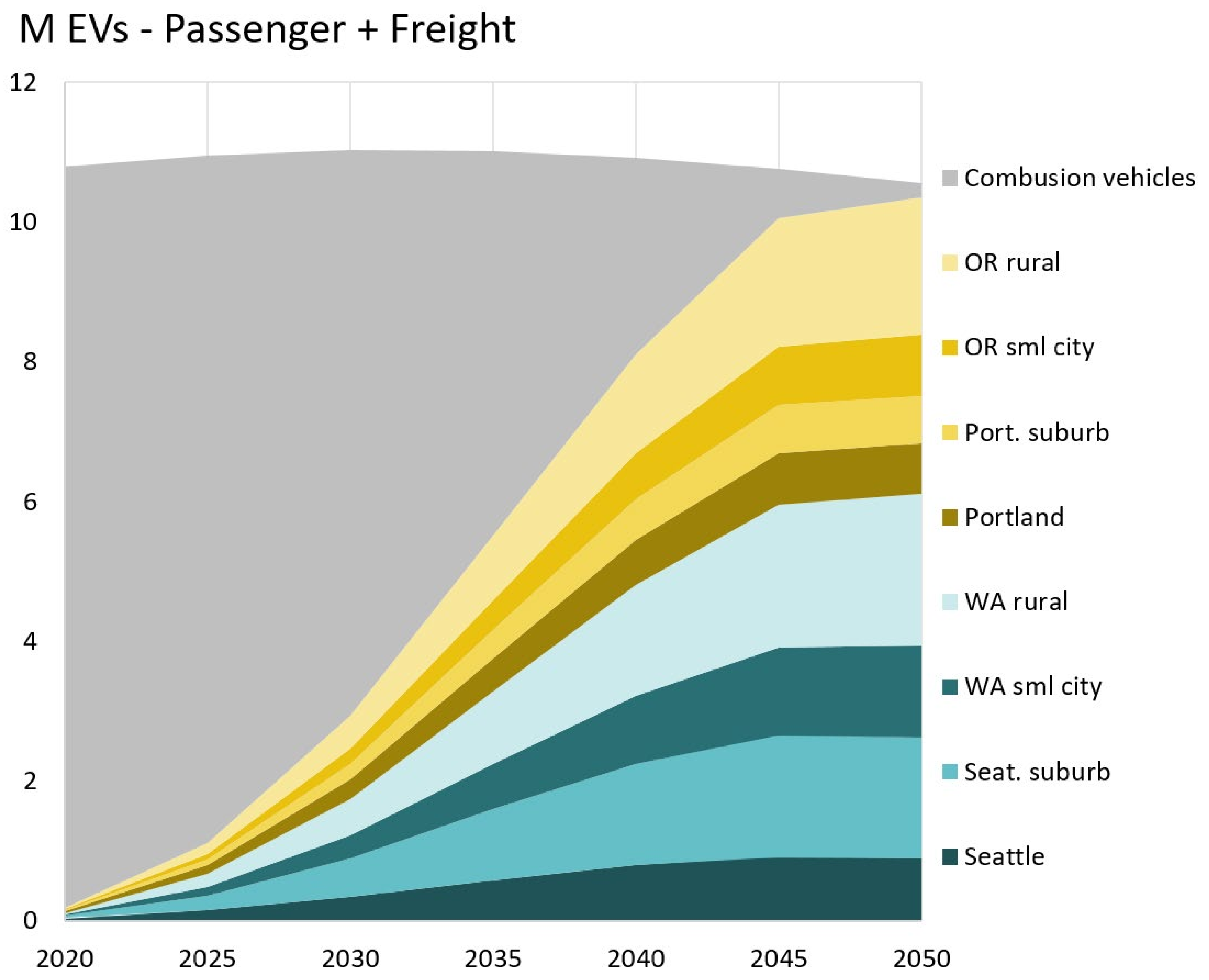




SCENARIO 1: ↓VMT + ⚡

Electrification Infrastructure

Vehicles



Chargers

750,000 chargers needed

Total cost = $1.2—2.4 billion

SCENARIO 1: ⬇ VMT + ⚡

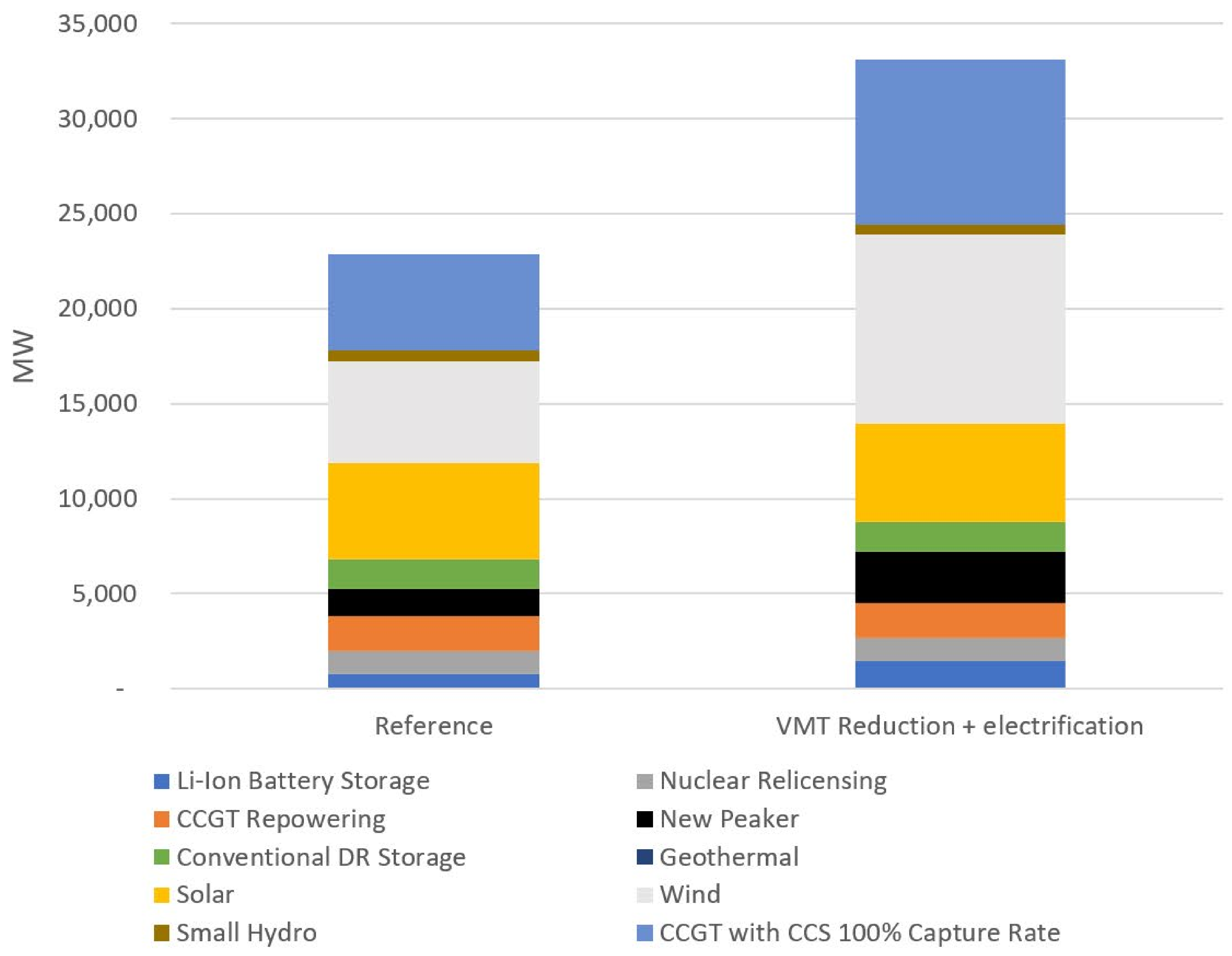
ELECTRICITY BY THE NUMBERS

System cost	$18.89 B +	$5.63 B =	$24.52 B

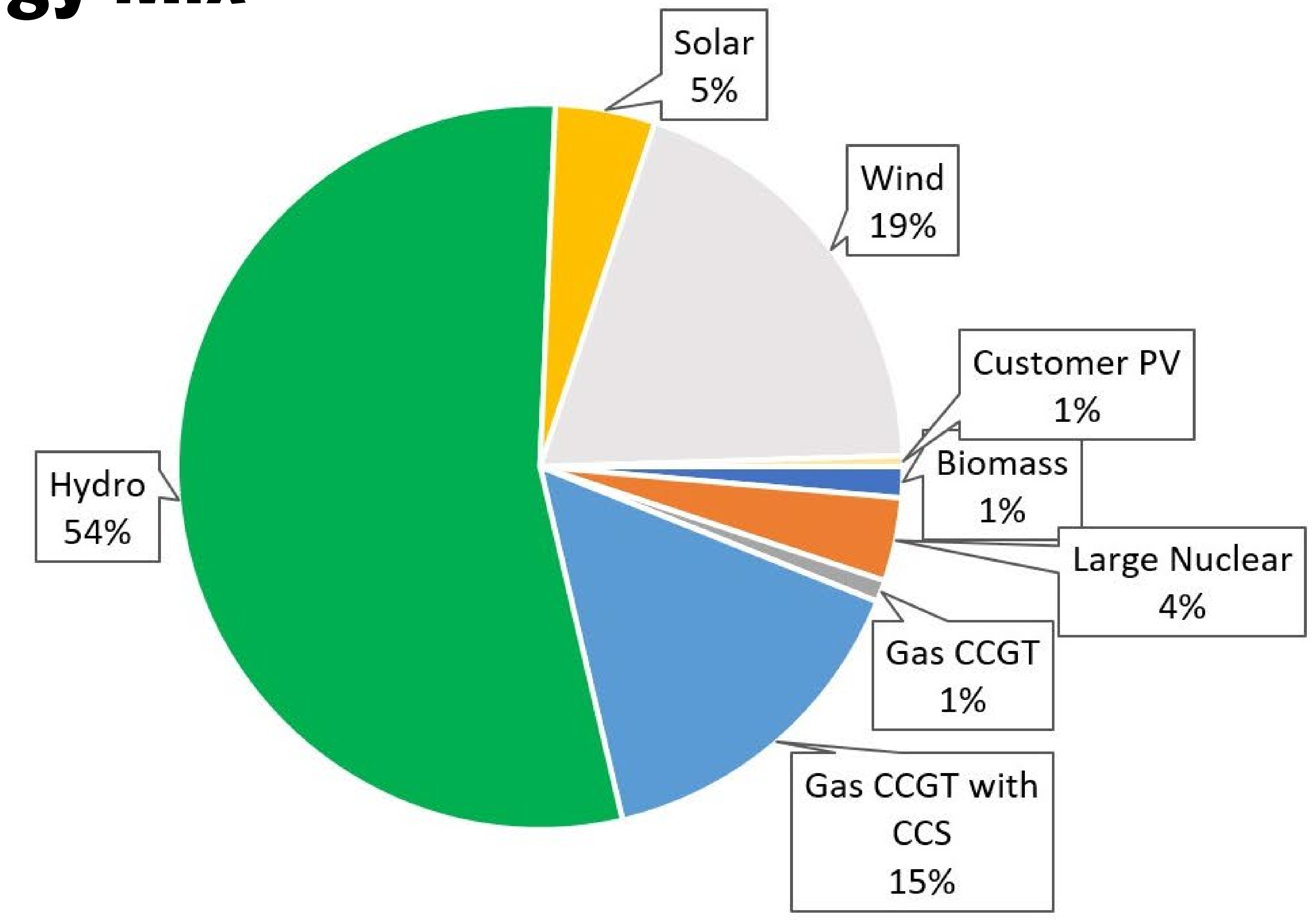
Total load (TWh) 198 **+39**

Peak Capacity (GW) 36 **+4.9**

Resource Builds 2050



Energy Mix

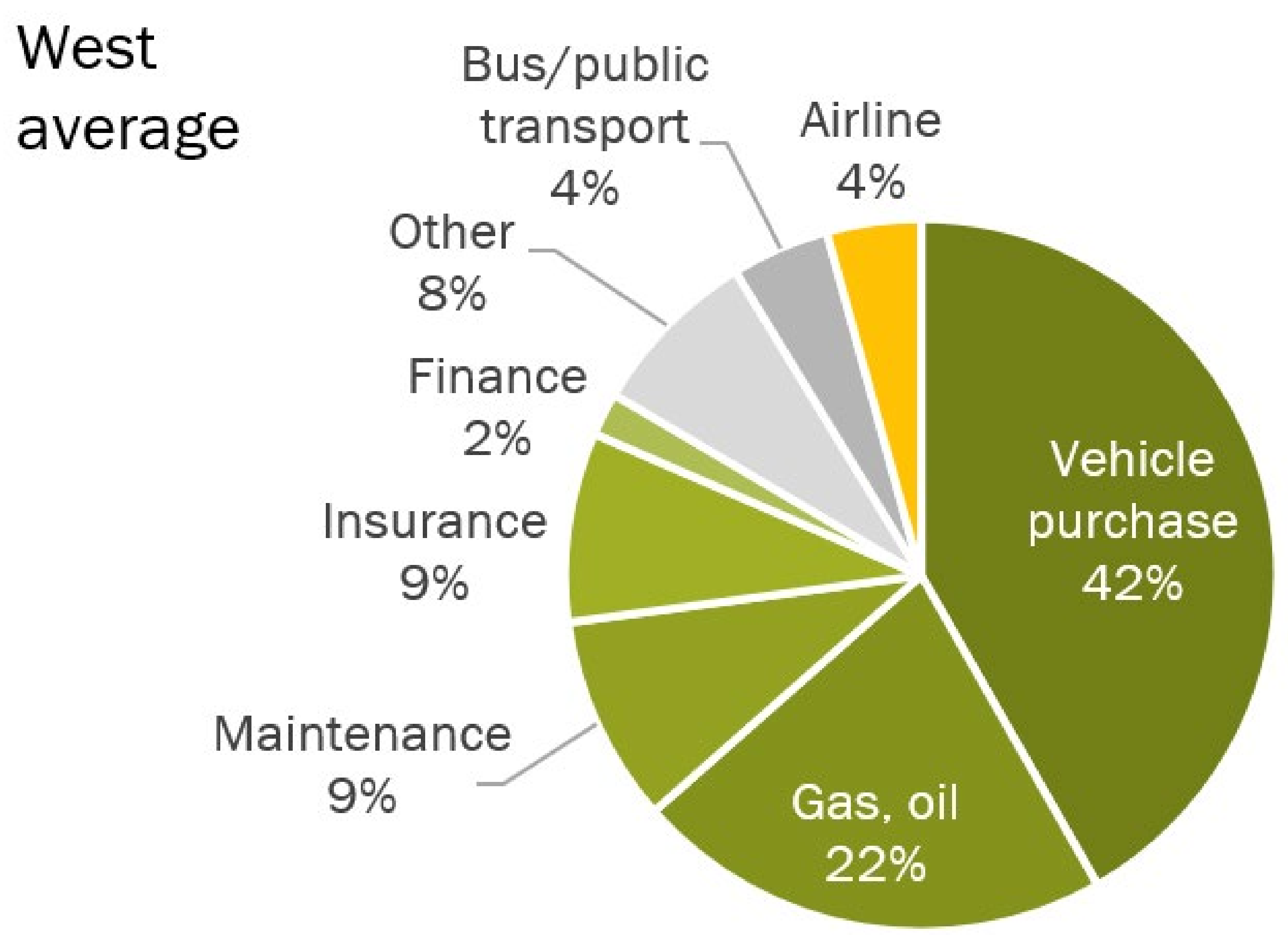


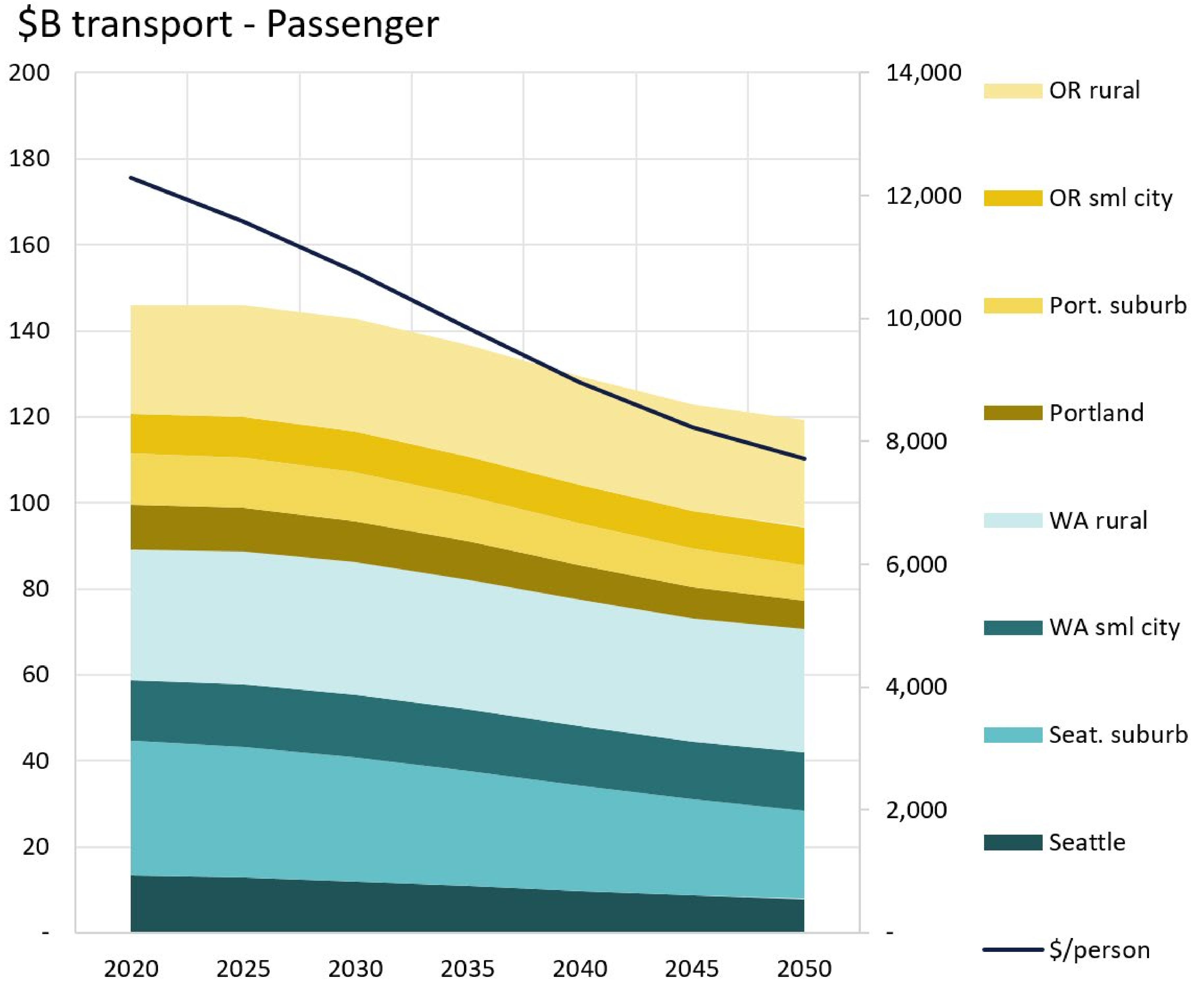
SCENARIO 1: ↓VMT + ⚡

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: ⬇ VMT + ⚡

Health Benefits from Reduced Tailpipe Emissions

Change vs. Business as Usual

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

*Team analysis using EPA's COBRA model

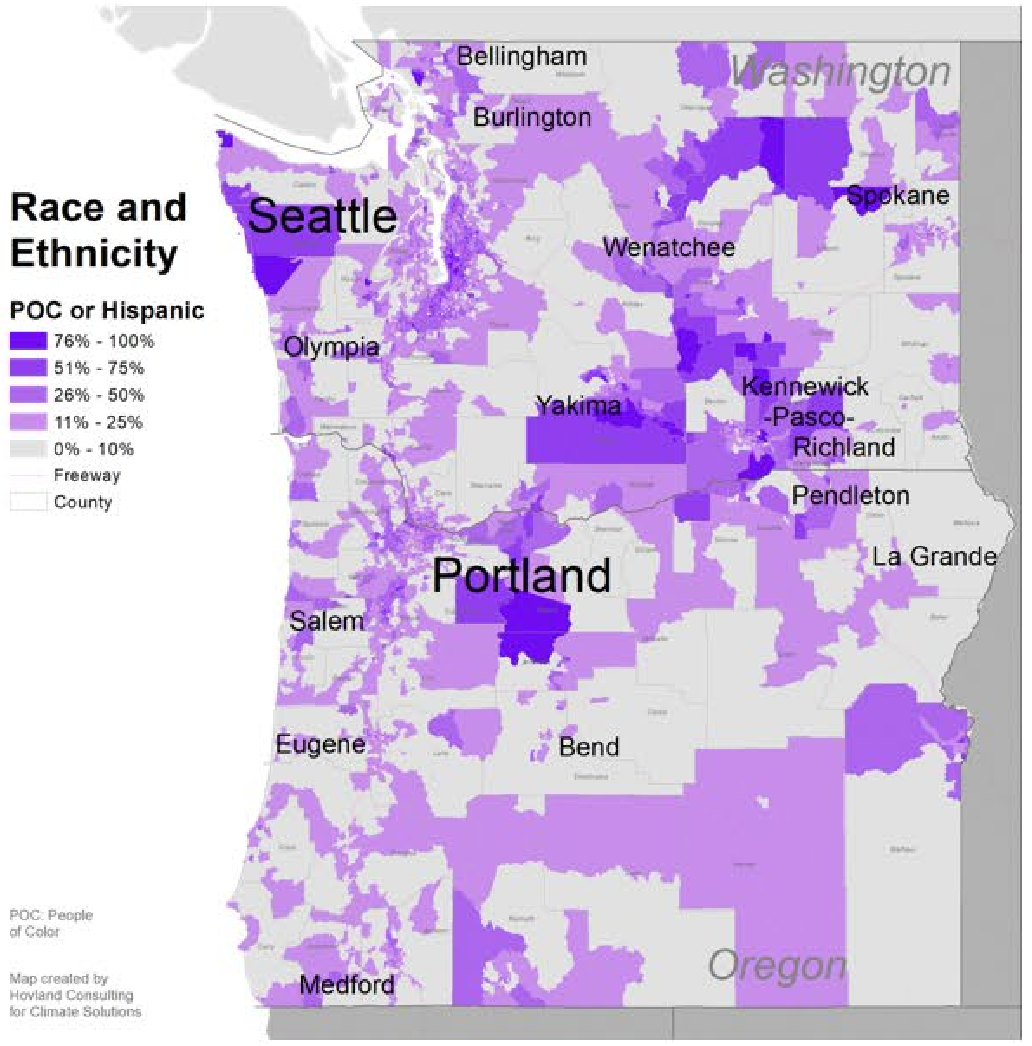
SCENARIO 1: ⬇VMT + ⚡

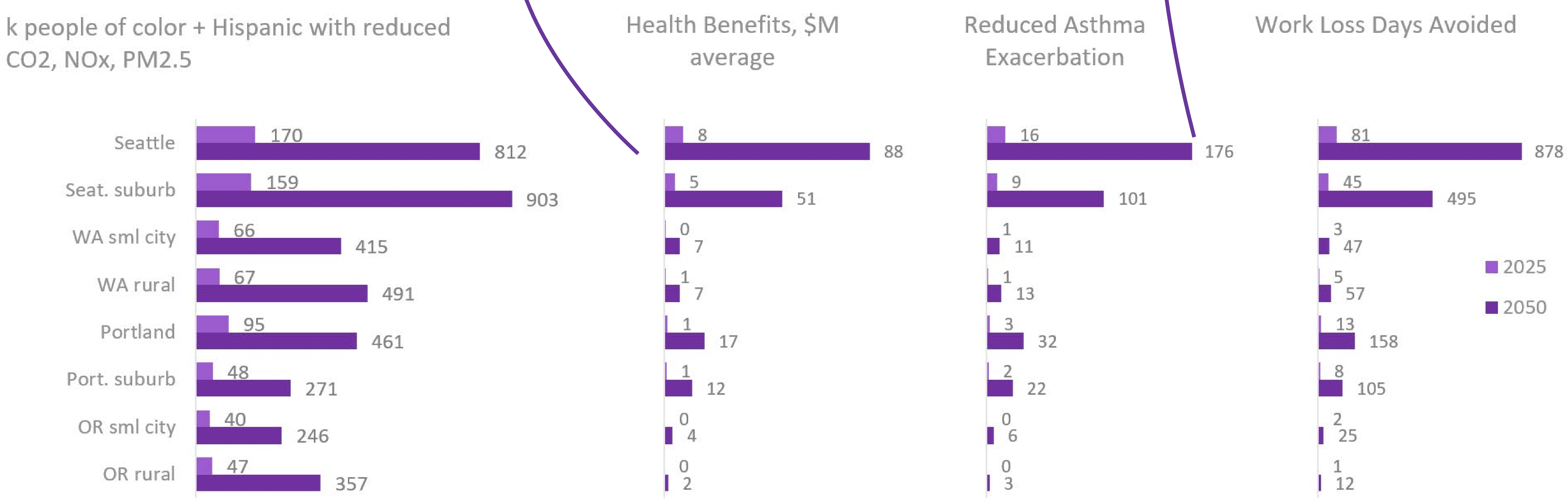
Total benefits for People of Color + Hispanic

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)

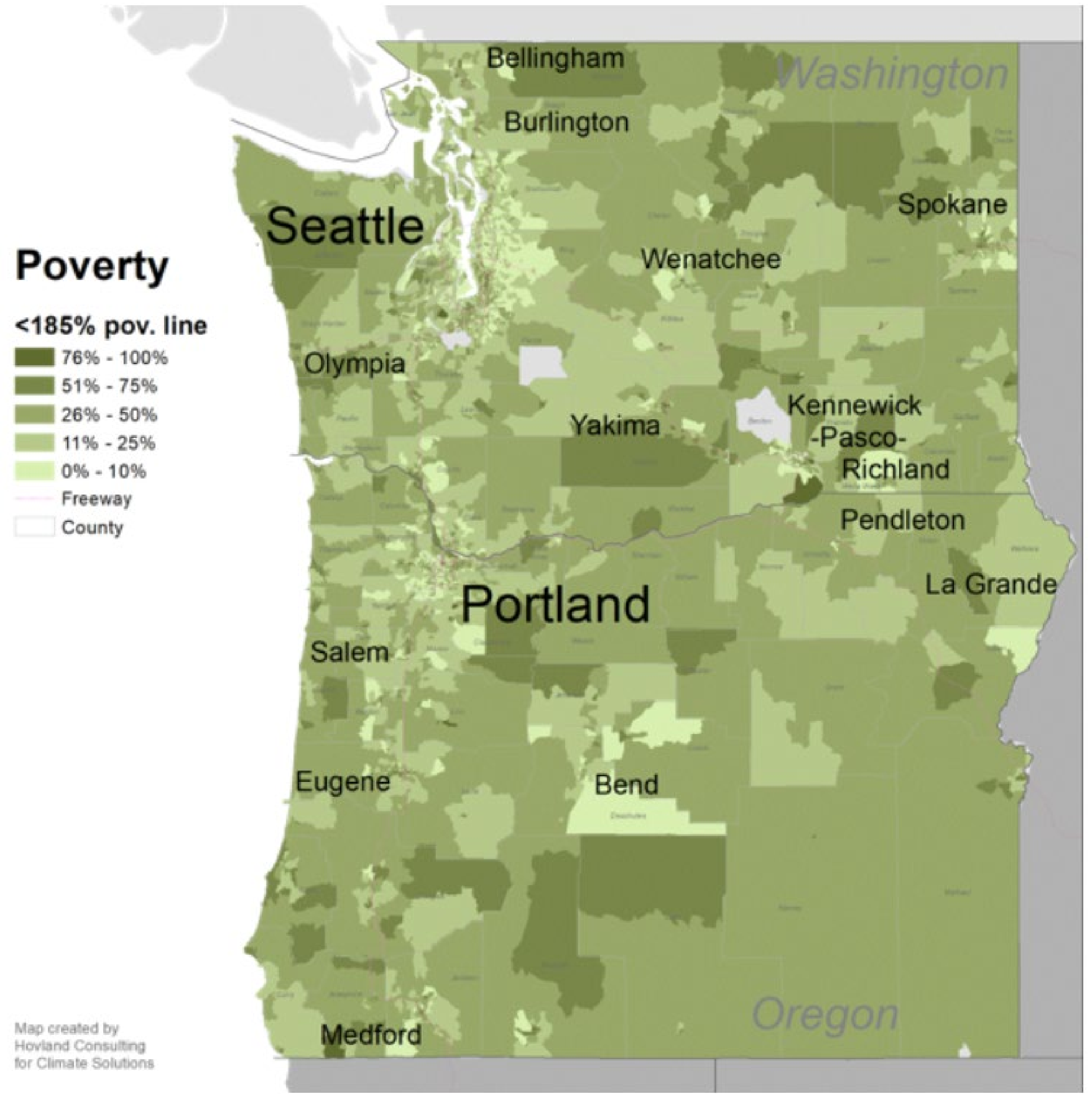




SCENARIO 1: ↓VMT + ⚡

Total benefits for low-income communities

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



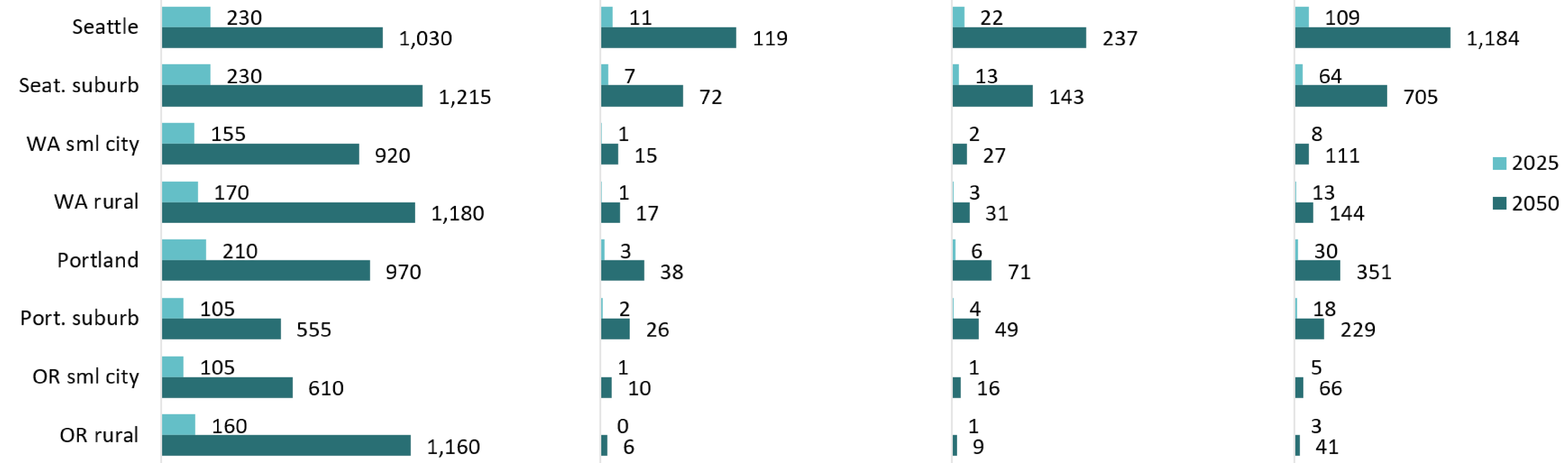
$55 million in avoided health costs by 2050

185% Poverty level

k people of in poverty with reduced CO2, NOx, PM2.5 | Health Benefits, $M average | Reduced Asthma Exacerbation | Work Loss Days Avoided

80% AMI

k people of in poverty with reduced CO2, NOx, PM2.5 | Health Benefits, $M average | Reduced Asthma Exacerbation | Work Loss Days Avoided



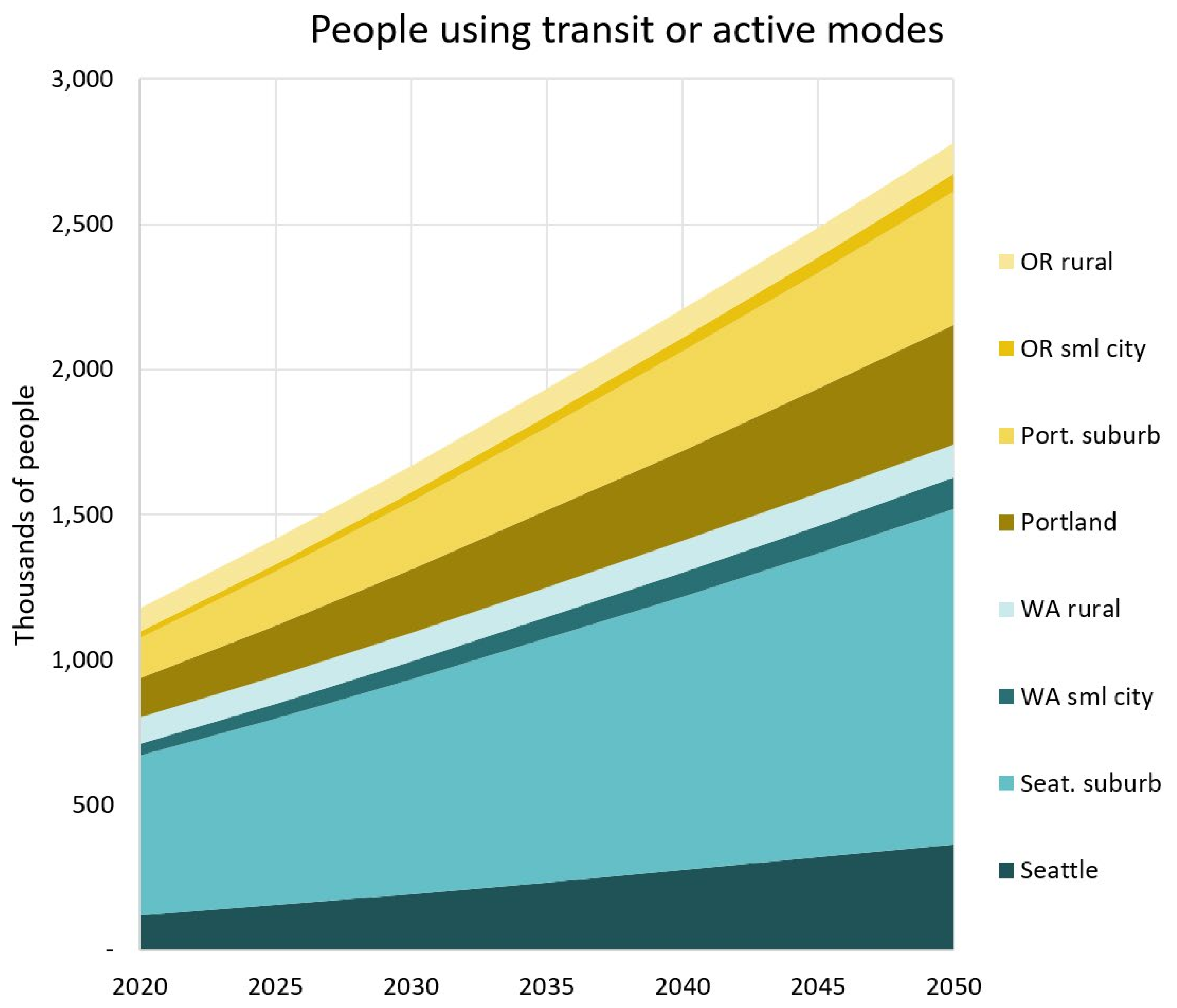
SCENARIO 1: ⬇ VMT + ⚡

Active Mobility

Compared to business as usual:

1 million more people using buses

250,000 more people walking, biking, or using micromobility options

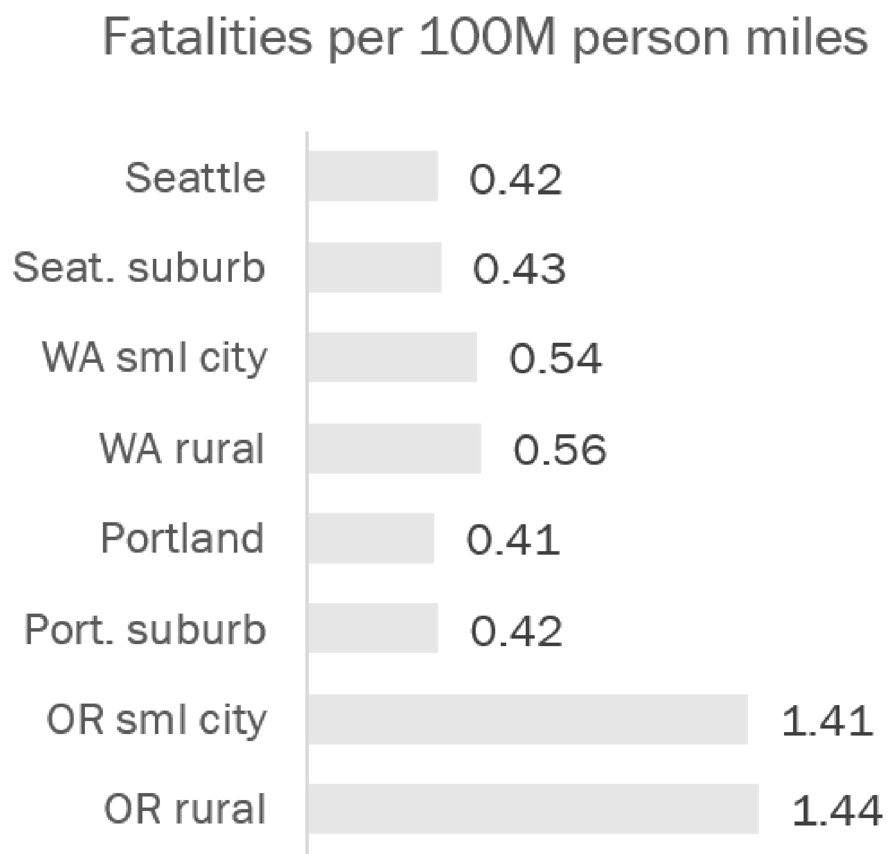


SCENARIO 1: ⬇VMT + ⚡

Crash Fatalities

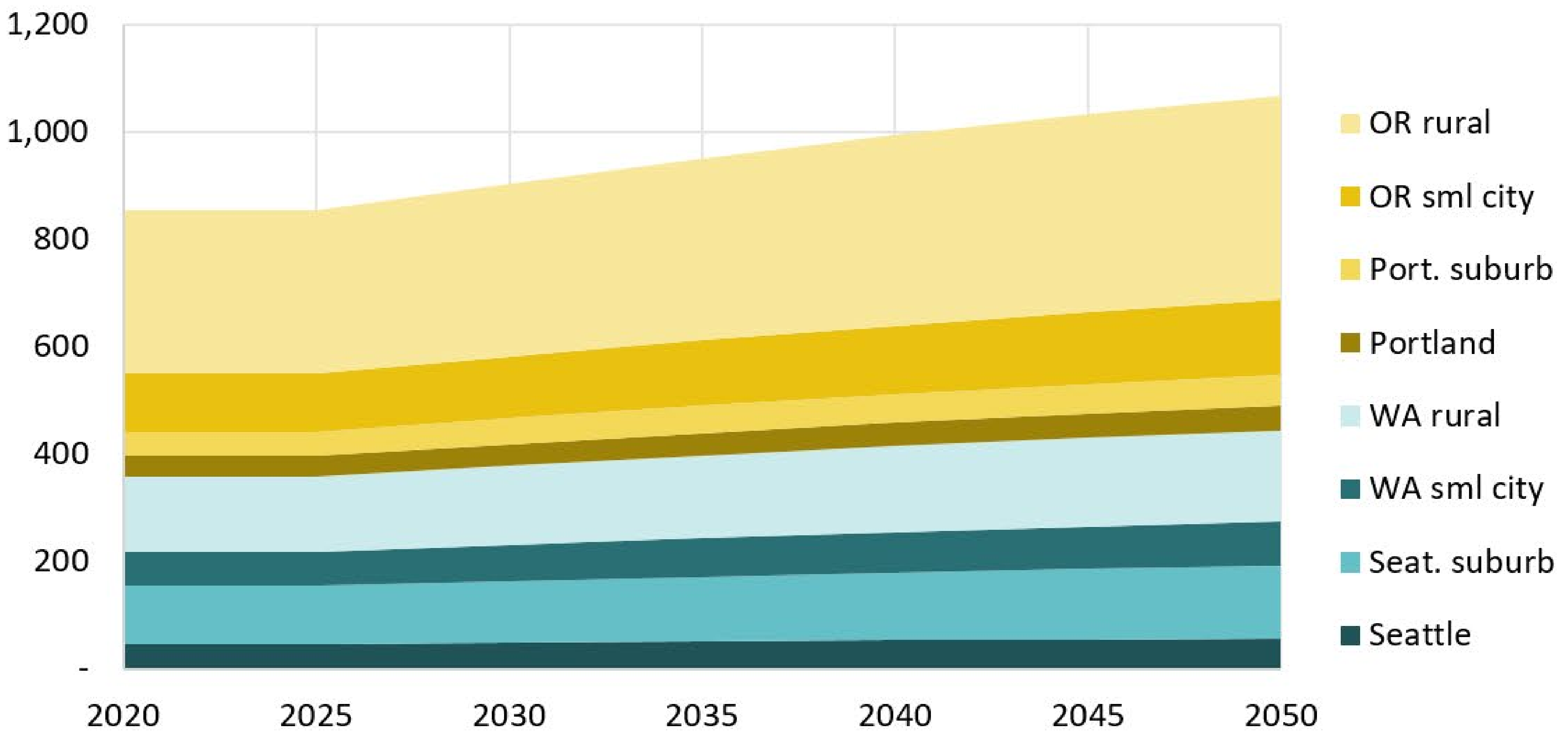
205 lives are saved in 2050 (and 42 in 2030) as a result of reduced VMT.

Small cities and rural areas in OR have high fatality rates



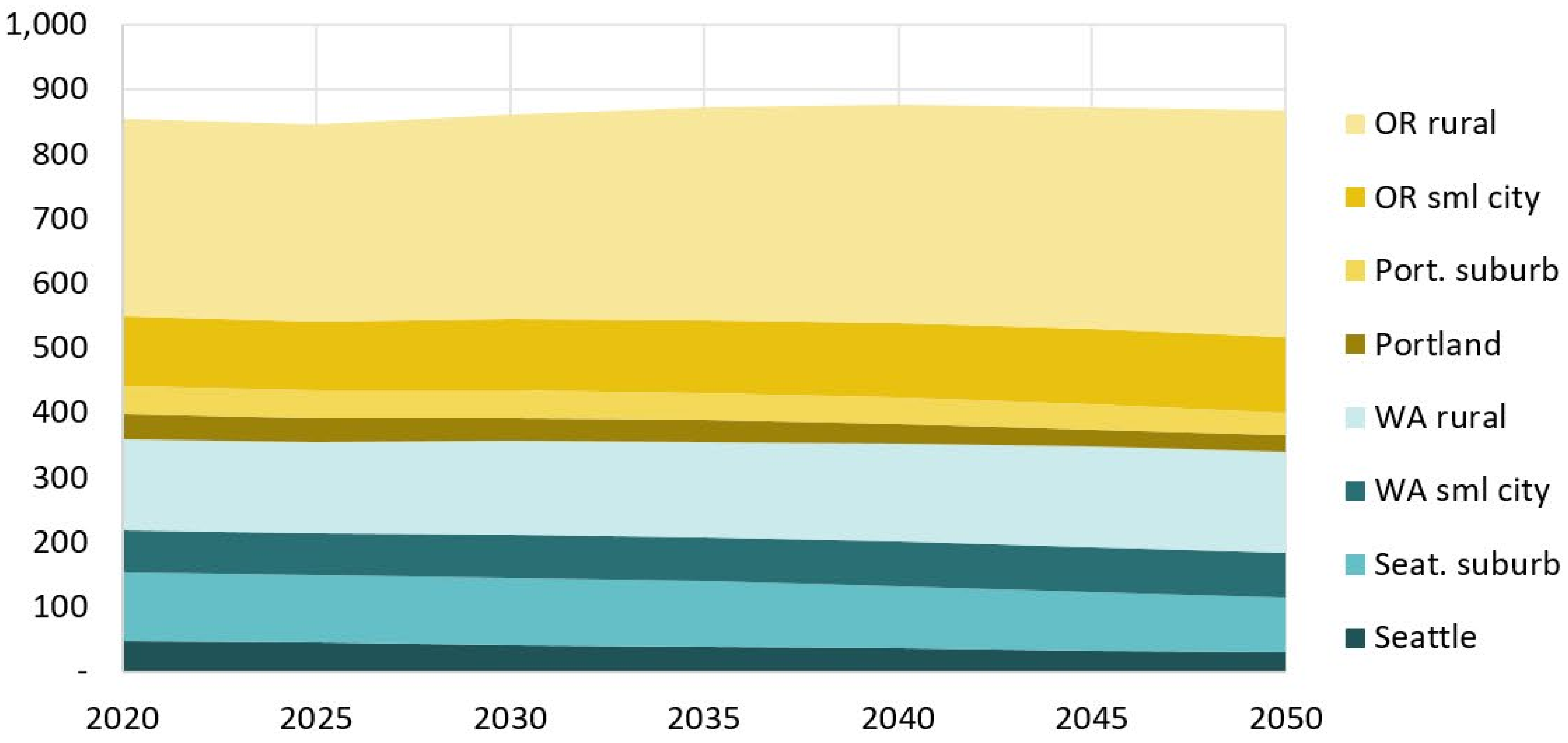
Reference Case (business as usual)

Fatalities - Passenger



Scenario 1

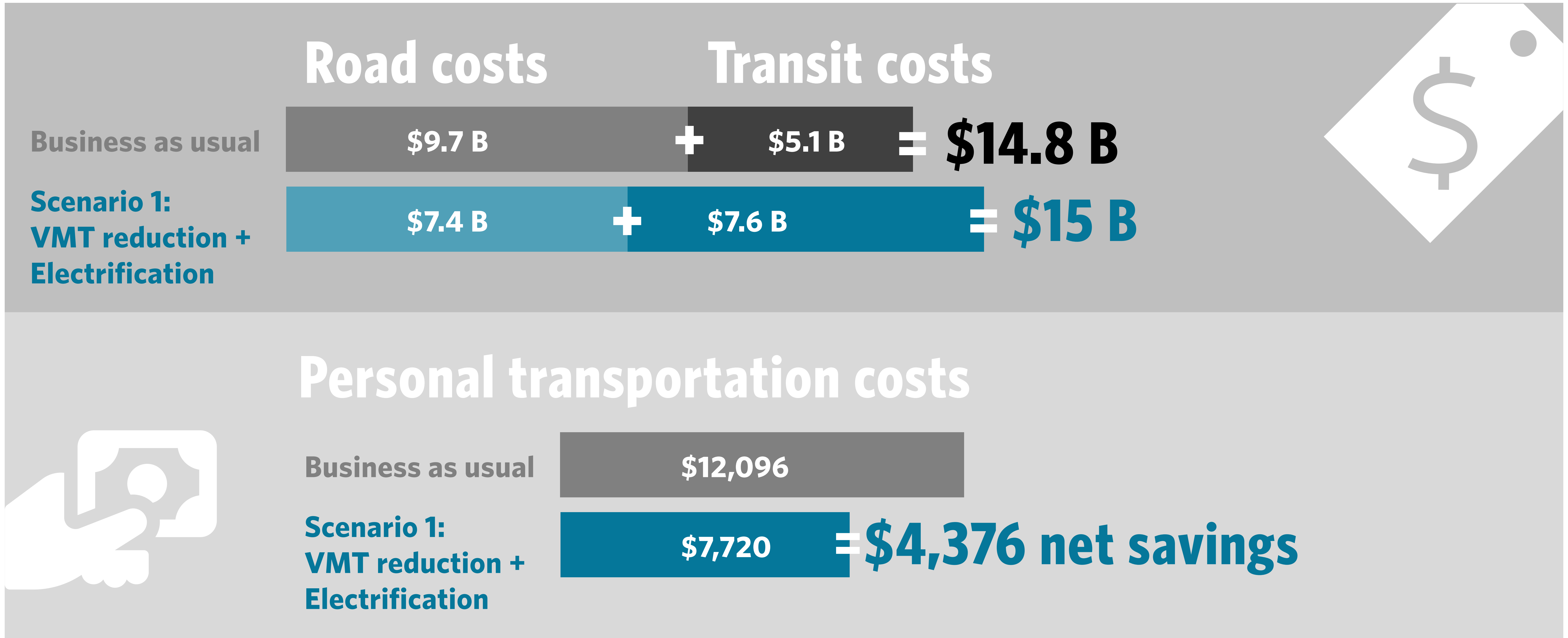
Fatalities - Passenger



SCENARIO 1: VMT +

Annual Direct Costs

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

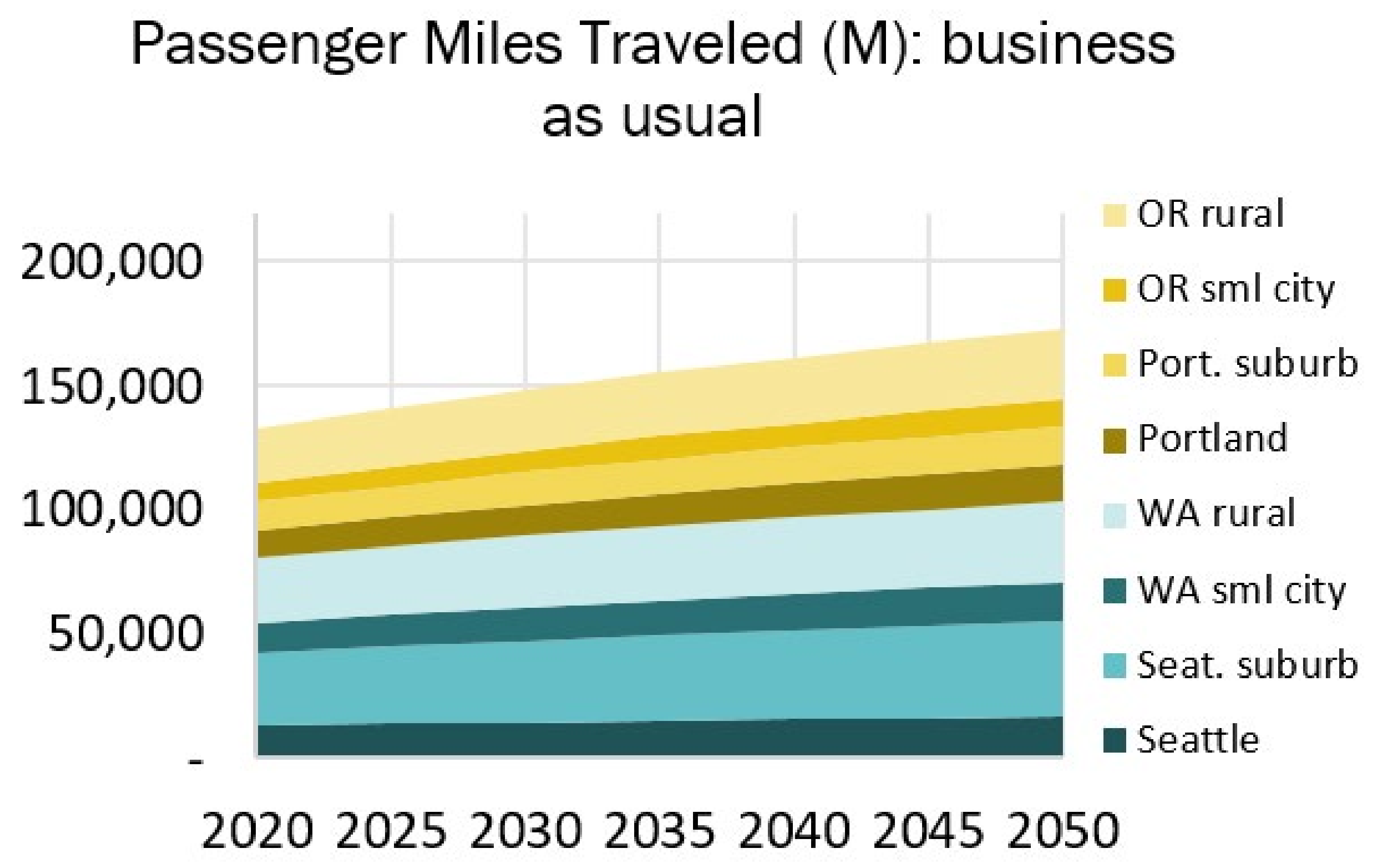


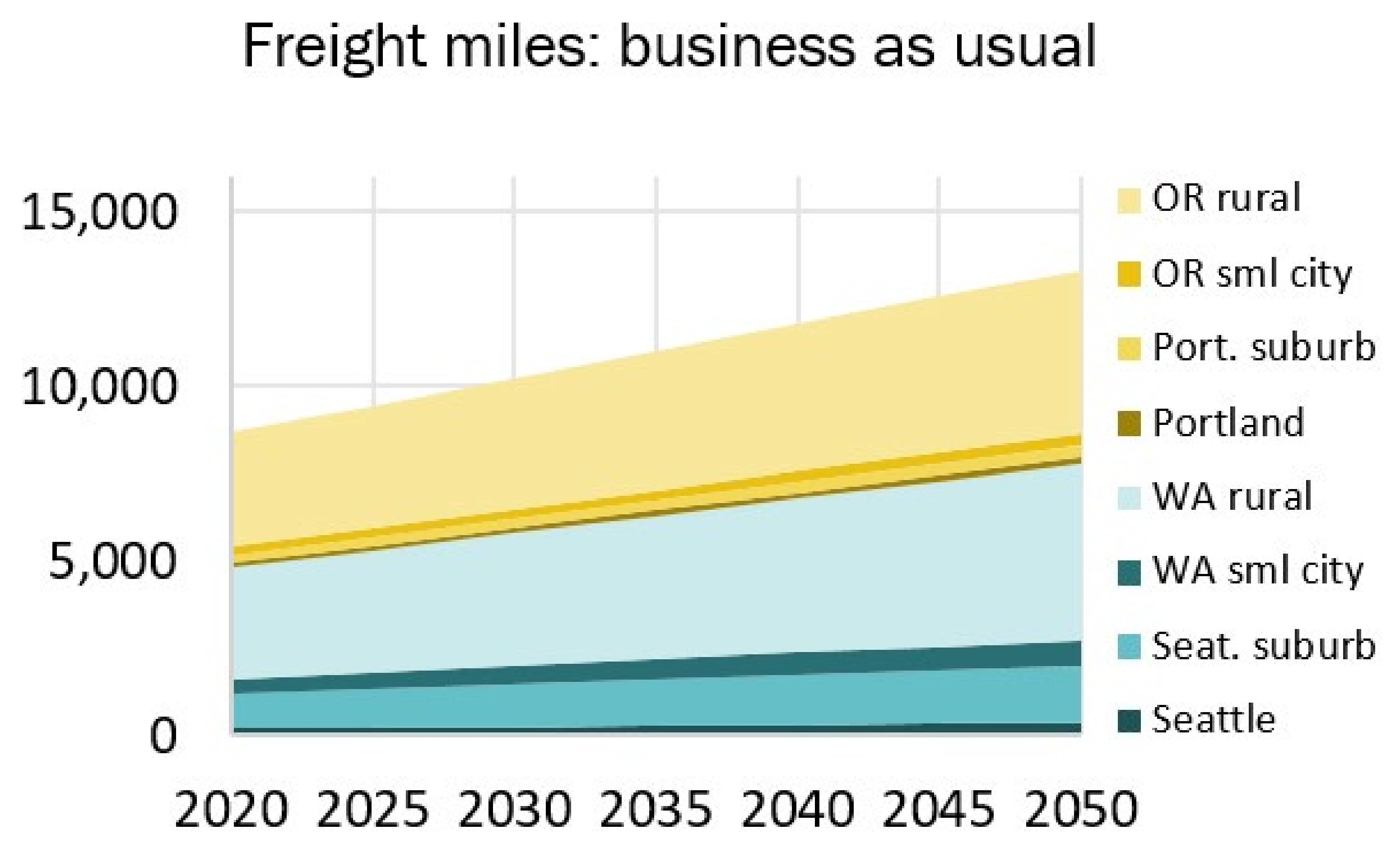
SCENARIO 2:
100% ELECTRIC (ALMOST)

Electrification only

COULD WE JUST GO 100% ELECTRIC?

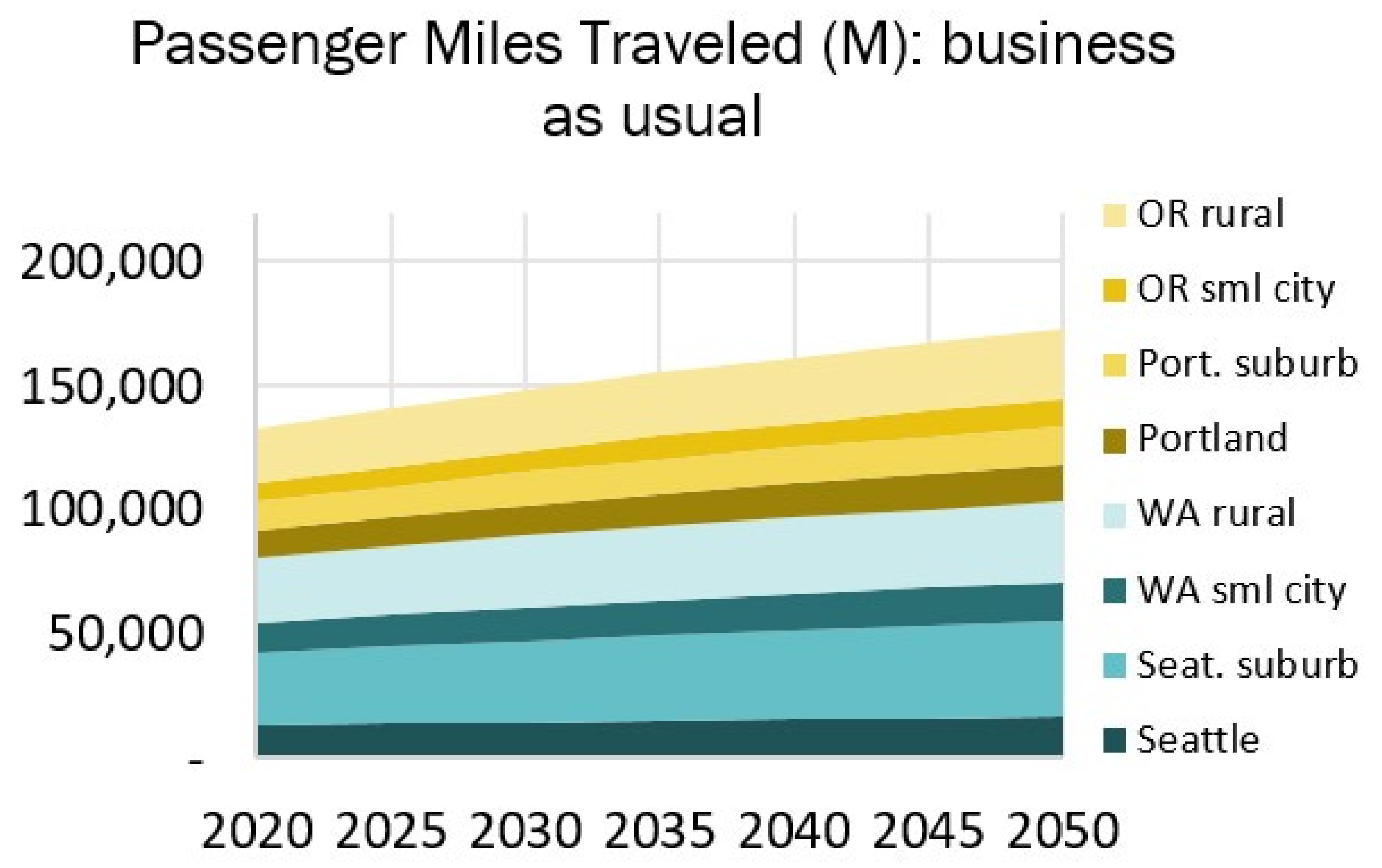
A fully electrified transportation system yields ***significant health benefits*** with only zero emission vehicles on the road.

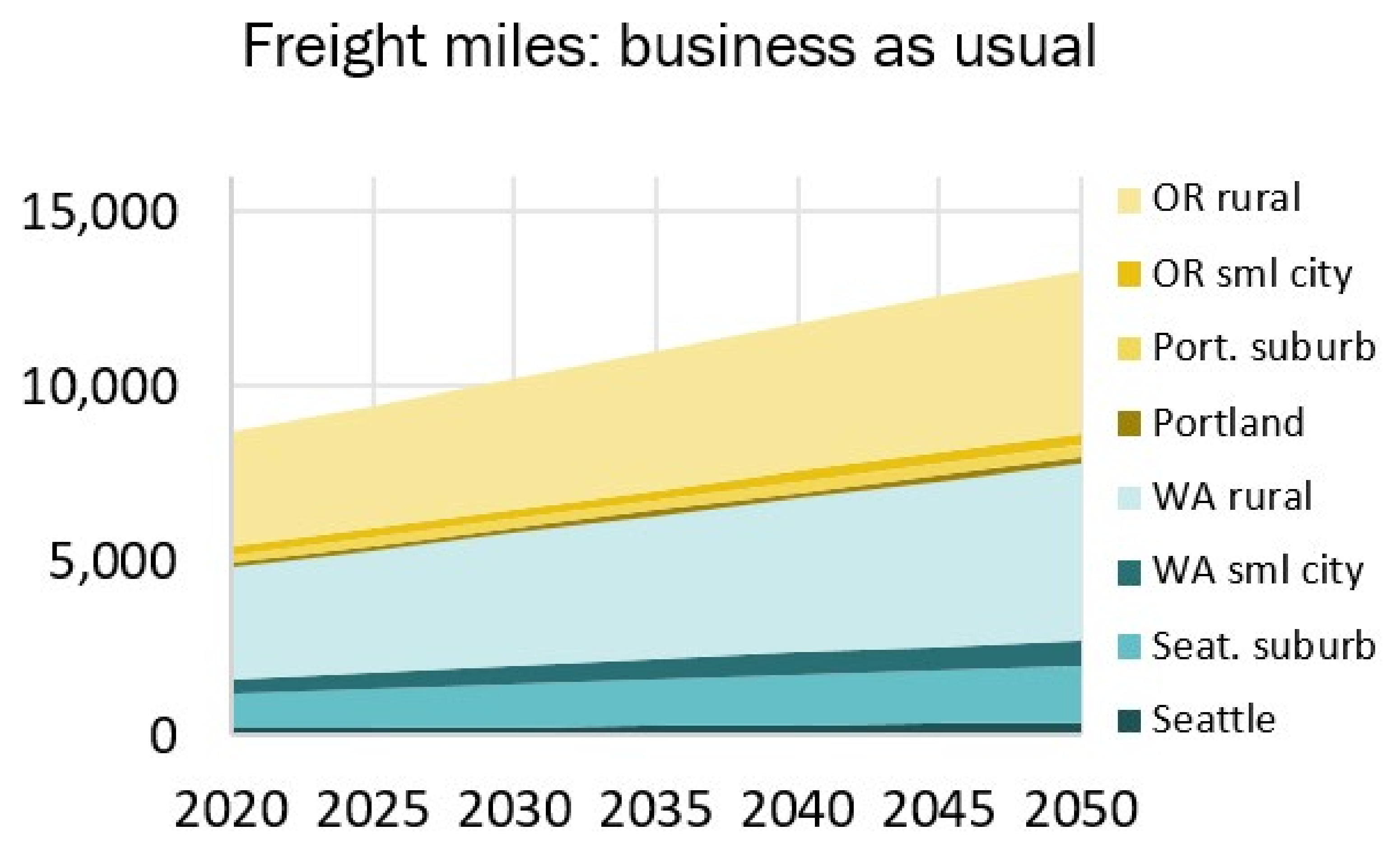




IT WOULD REQUIRE **SIGNIFICANT** CHANGE AND INVESTMENTS.

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.

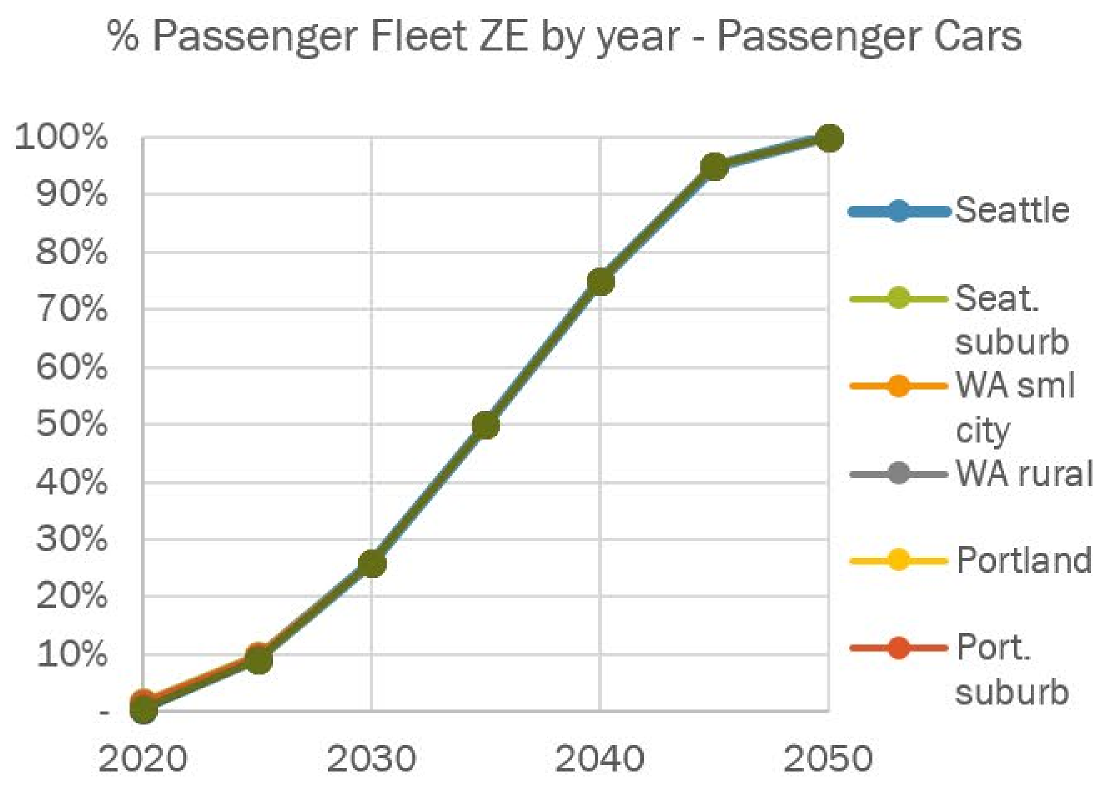


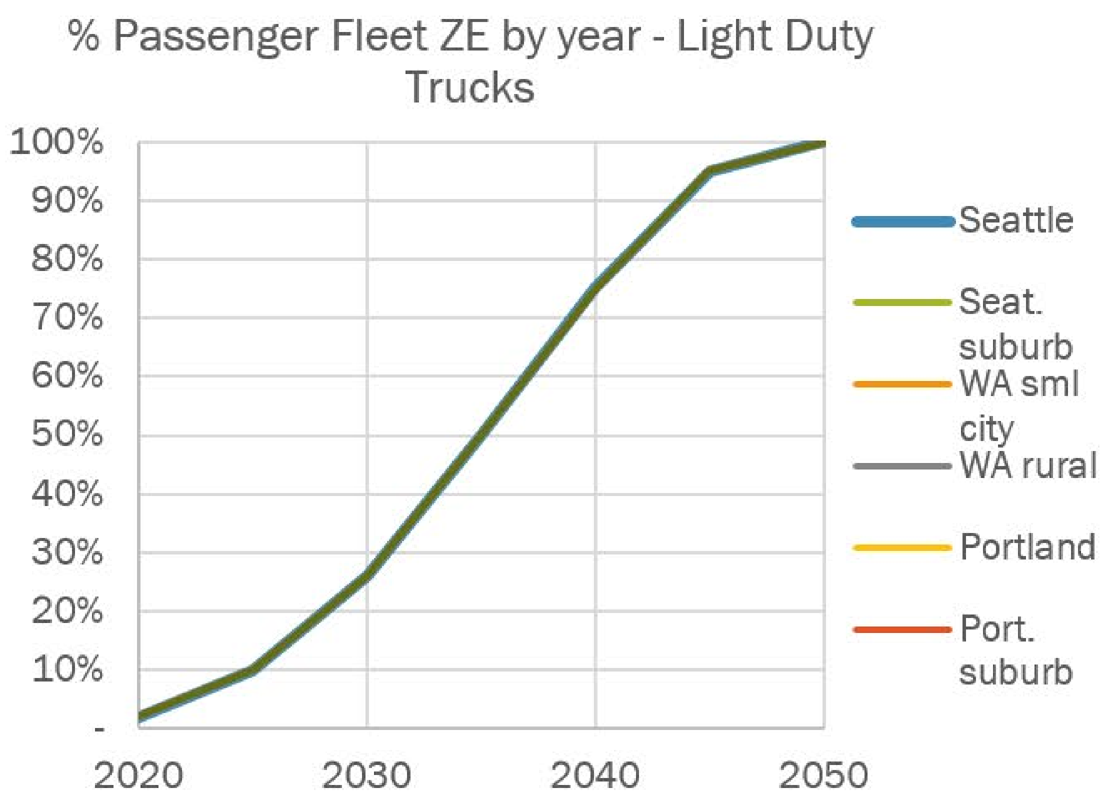


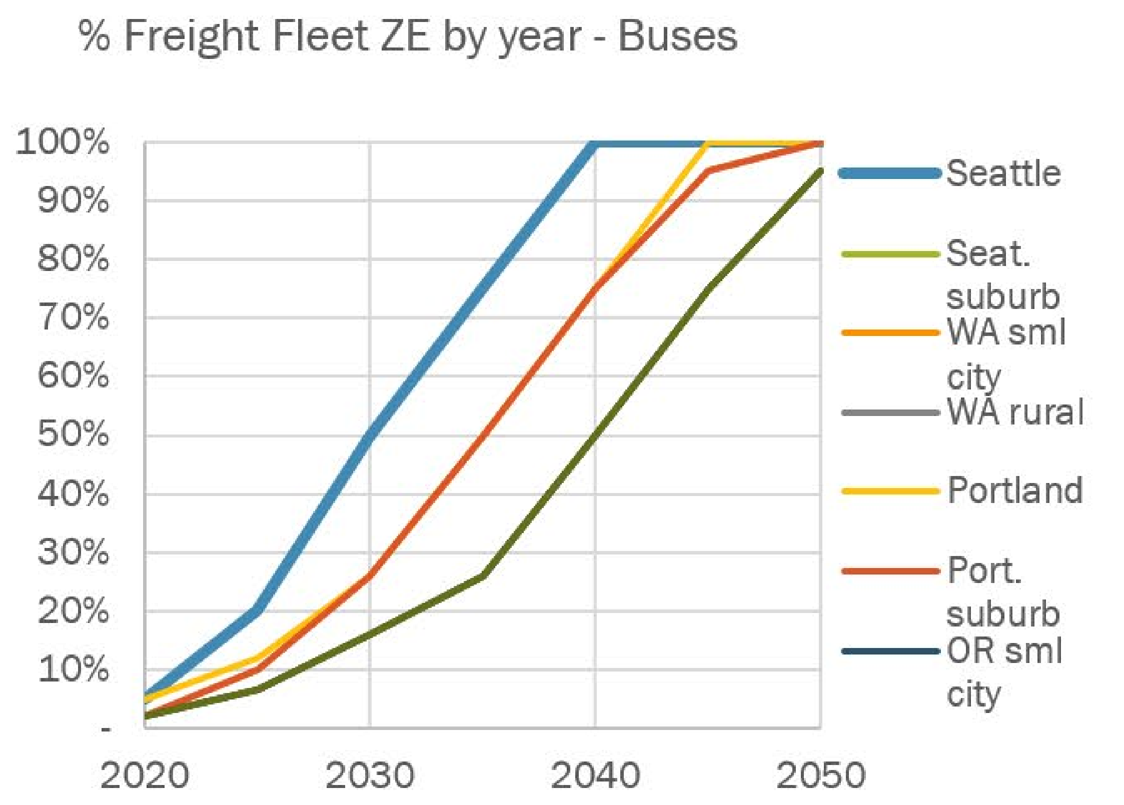
SCENARIO 2: Near 100%

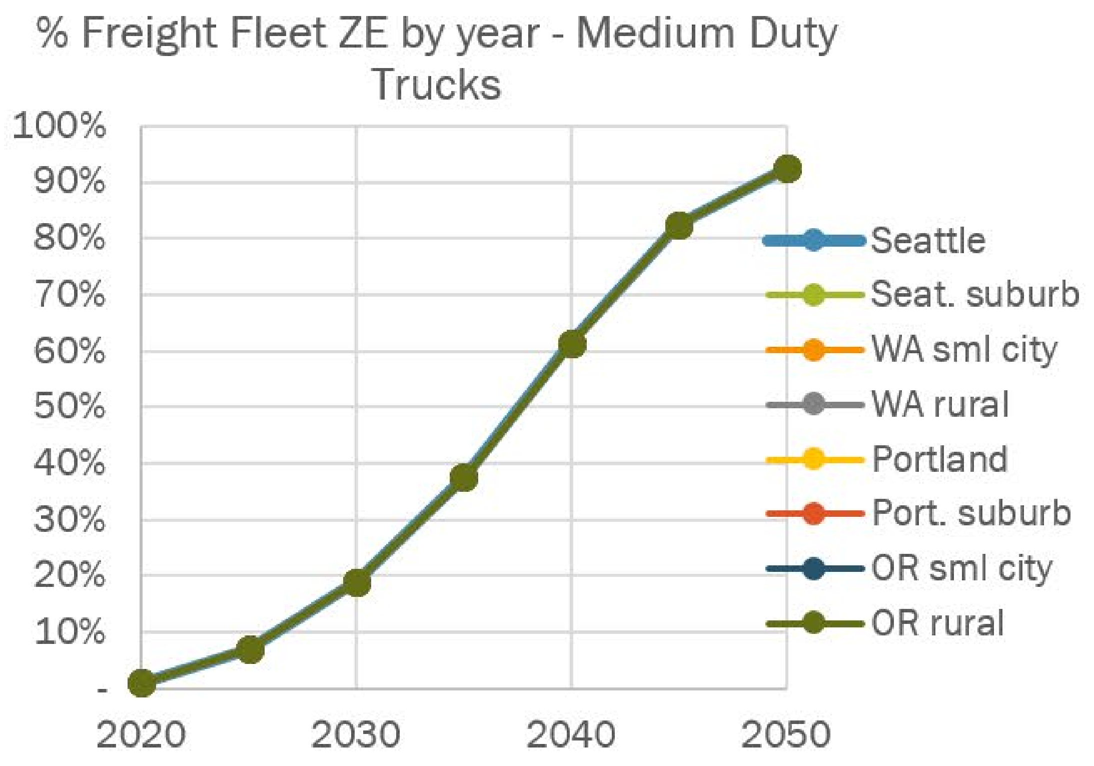
Near-100% electrification & business as usual VMT

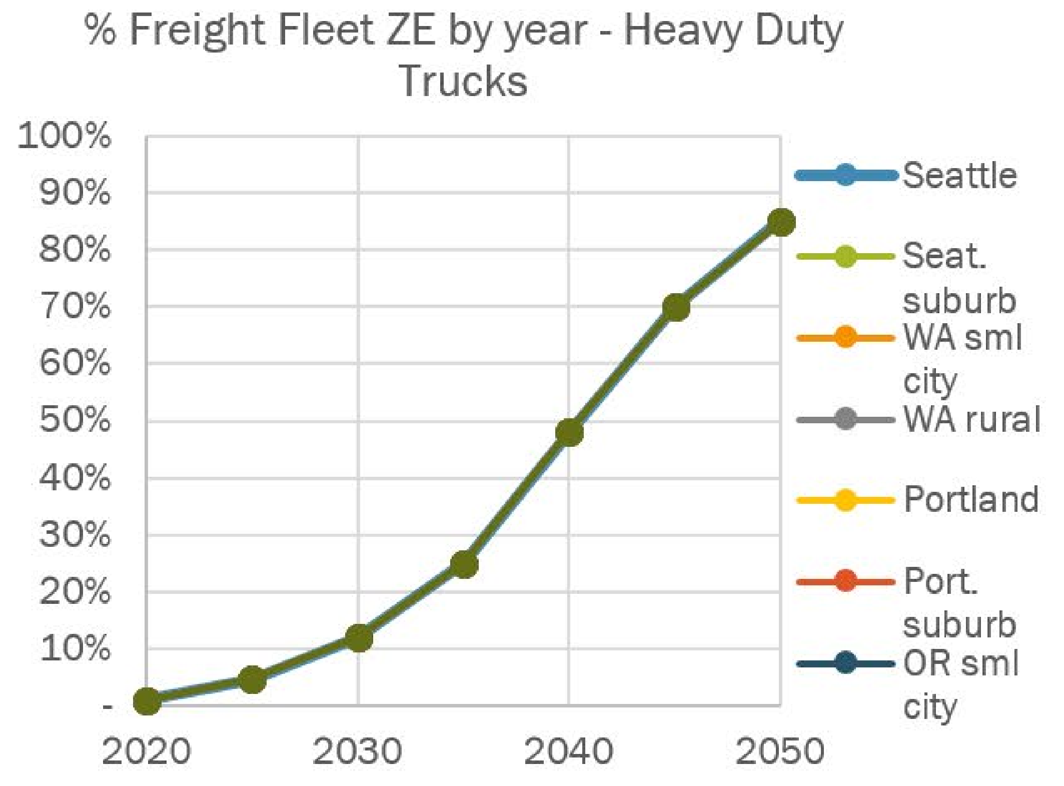
What if we just made everything electric and kept our behavior the same? Could we still meet our decarbonization goals?





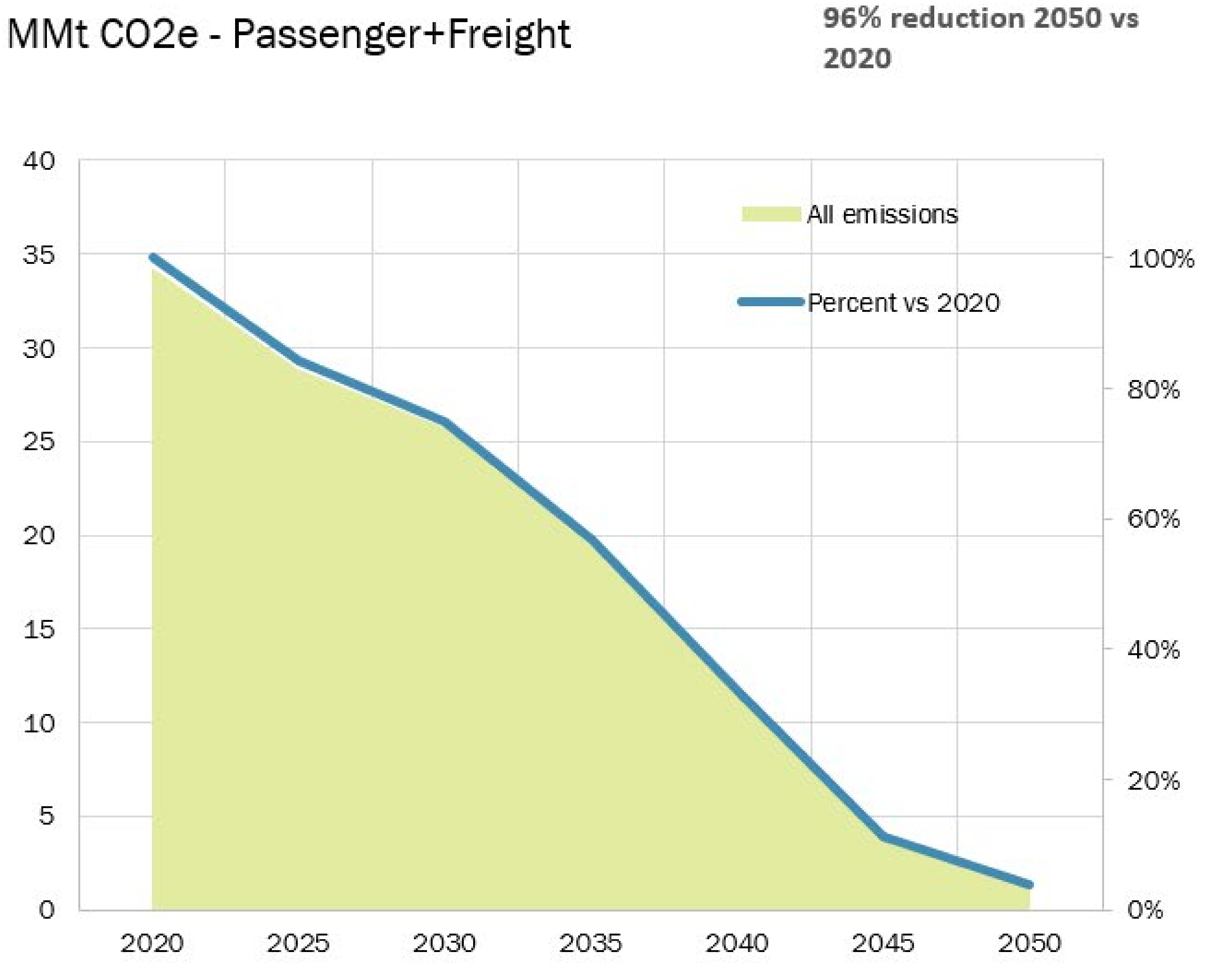




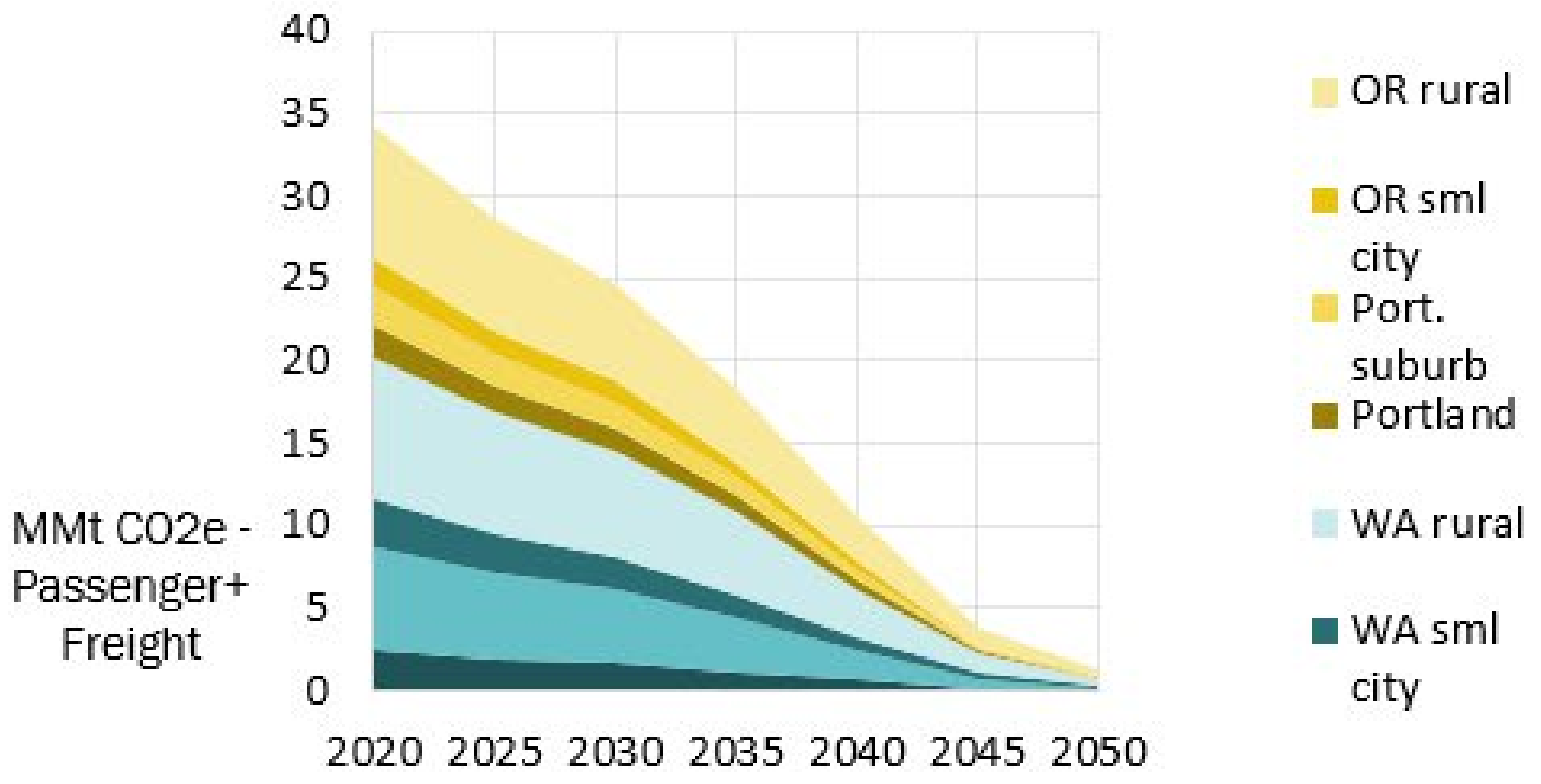


SCENARIO 2: Near 100%

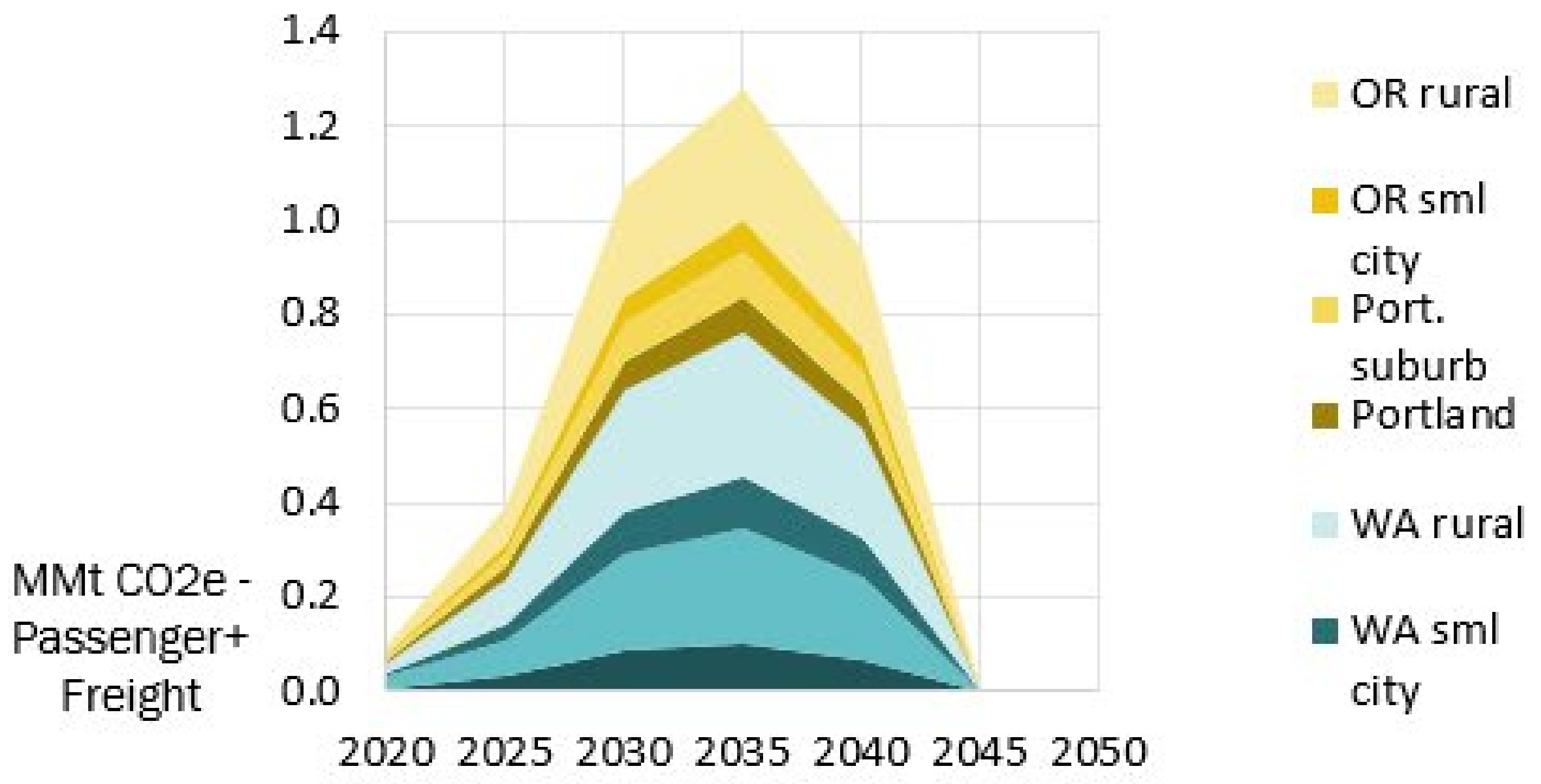
Greenhouse Gas Emissions



Scope 1 Tailpipe Emissions



Scope 2 Electricity Emissions



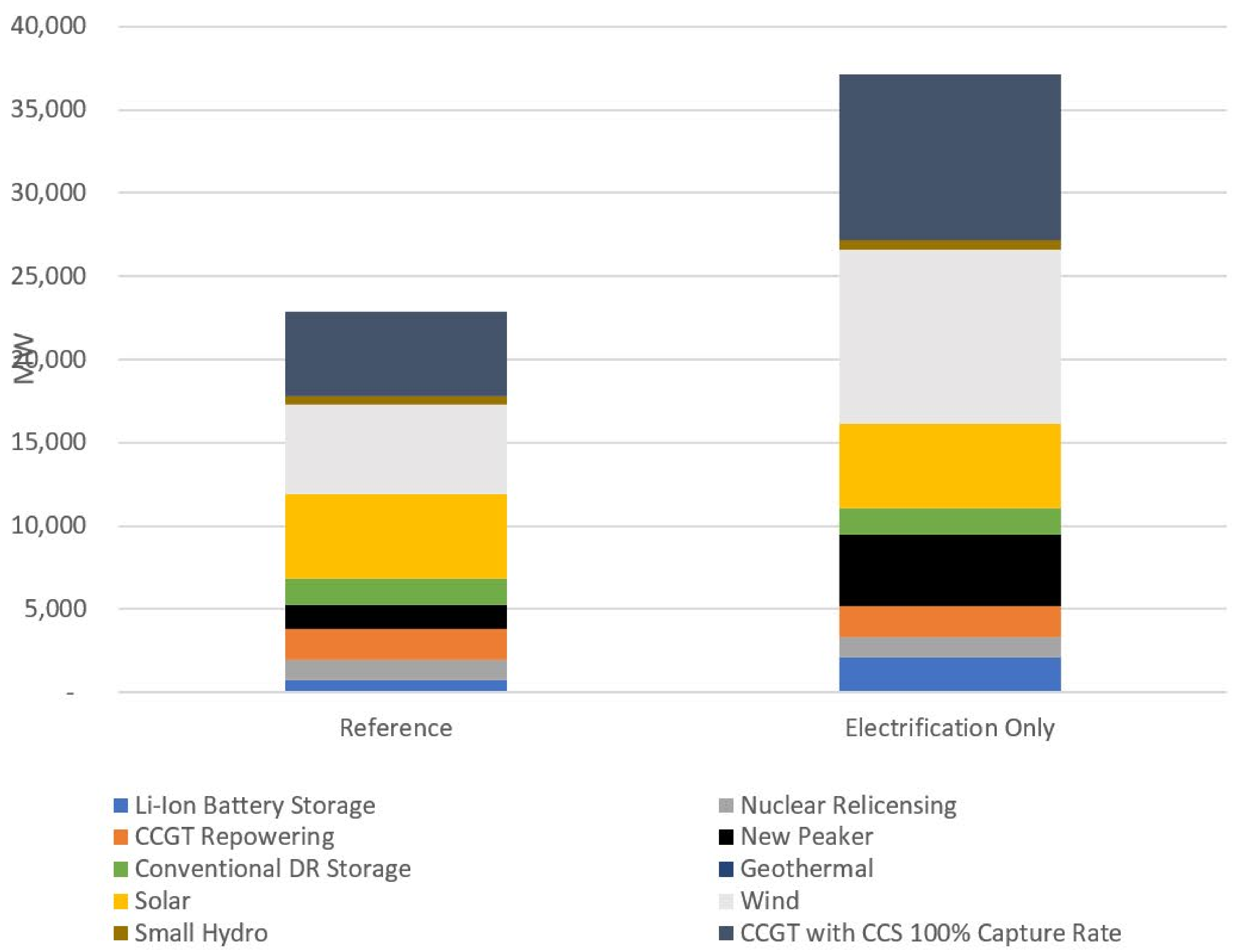
SCENARIO 2: 100%

ELECTRICITY BY THE NUMBERS

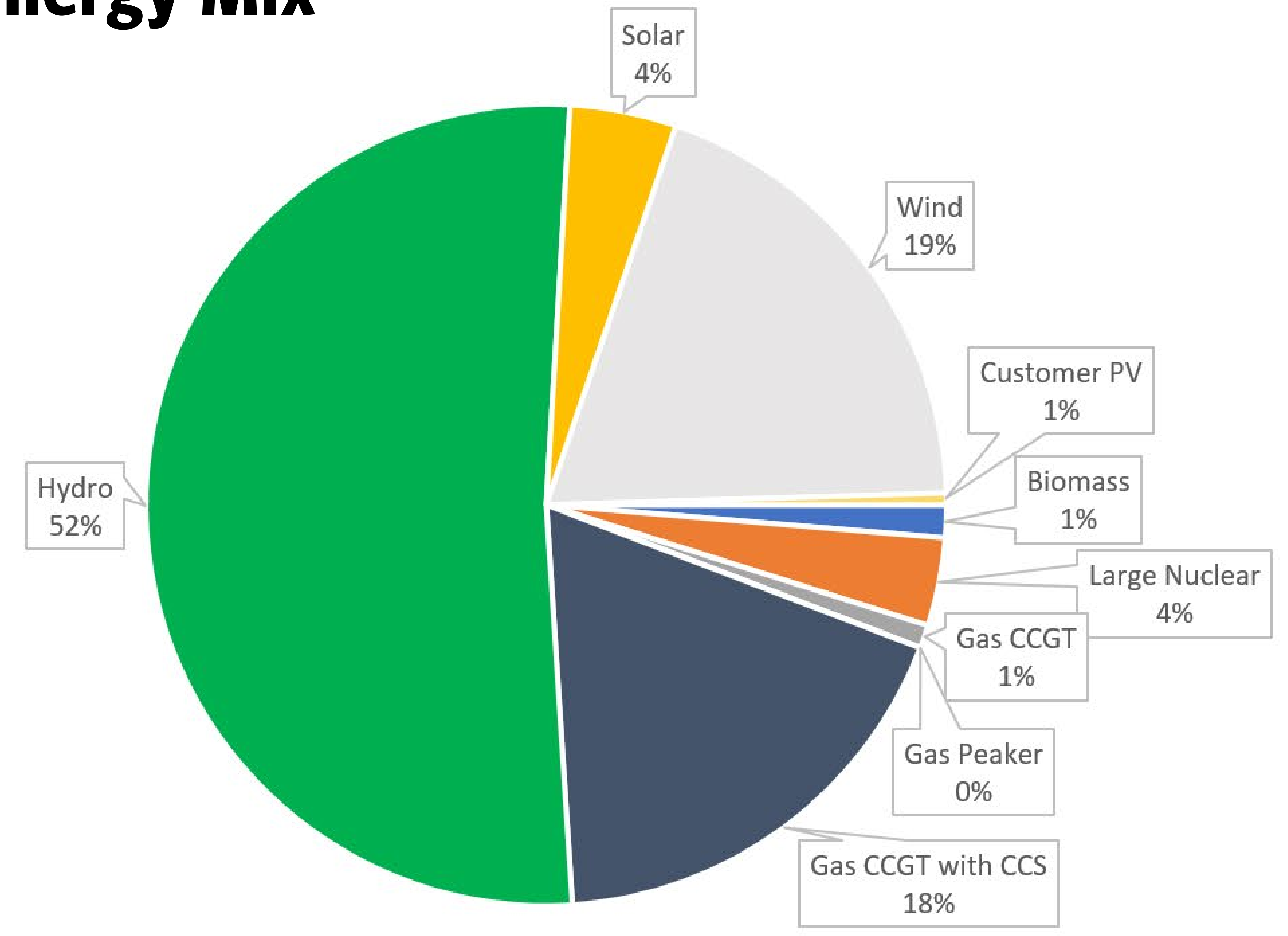
System cost $18.89 B + $7.4 B = $26.29 B

Total load (TWh) 198 +59 Peak Capacity (GW) 36 +9.7

Resource Builds 2050



Energy Mix



SCENARIO 2: Near 100%

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.

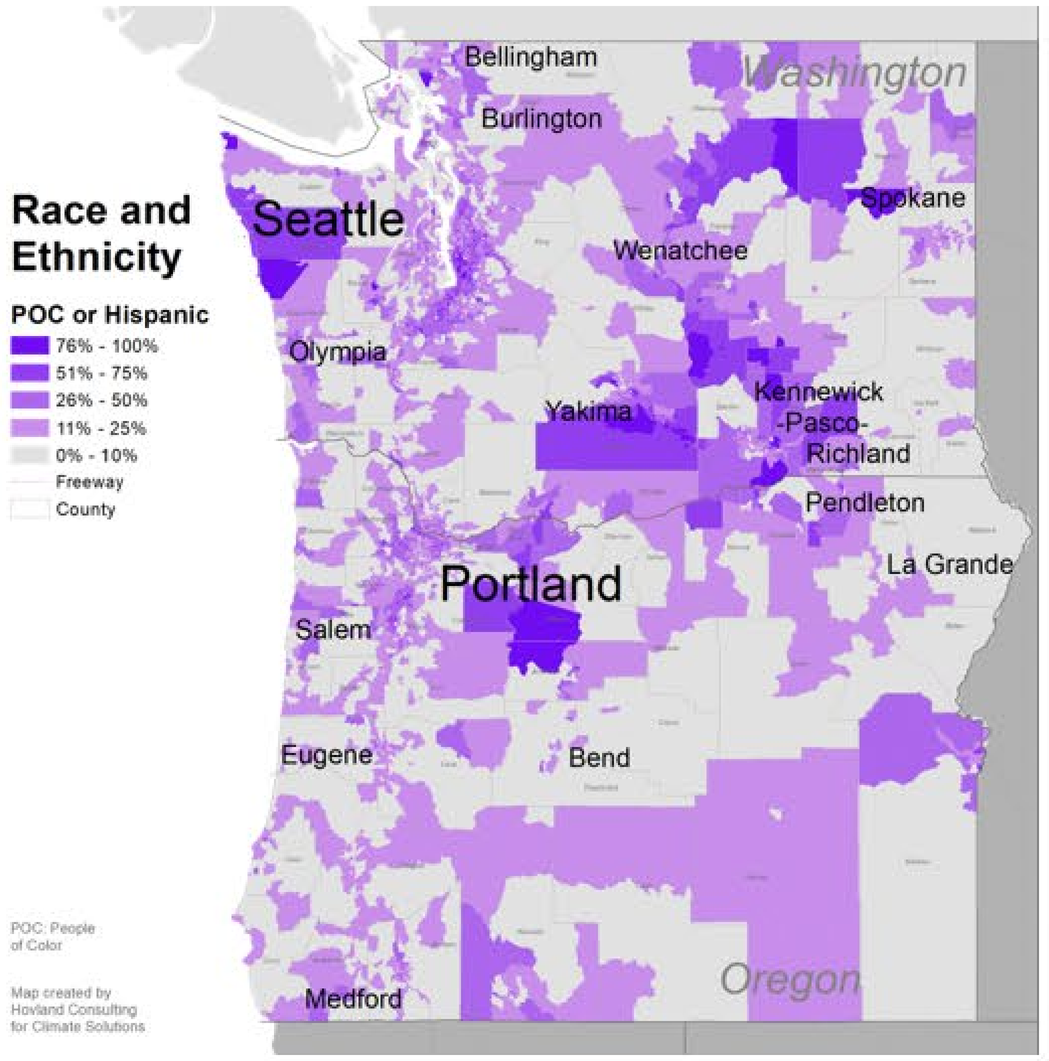
	Change from reduced VMT, 2050	Electrification + VMT reduction, 2050 (2025)	Electrification only 2050 (2025)
$ Total Health Benefits (low-high)	~similar	$626 – $278 M ($68 – $30 M)	$622 – $276 M ($44 – $20 M)
$ Hospital Admits reduced, All Respiratory	~similar	$186 k ($20 k)	$185 k ($13 k)
$ Work Loss Days avoided	~similar	$764 k ($83 k)	$761 k ($53 k)
$ Minor Restricted Activity Days avoided	~similar	$1,941 k ($210 k)	$1,931 k ($135 k)
Mortality avoided (low-high)	~similar	28 – 62 (3 – 6)*	28 – 62 (1 – 5)
Asthma Exacerbation avoided	~similar	875 (95)	875 (60)
Work Loss Days avoided	20 less	4,265 (460)	4,245 (295)
Minor Restricted Activity Days avoided	100 less	25,100 (2,700)	25,000 (1,700)

*** Additional avoided mortality from reduced crashes is independently modeled (not part of the COBRA modeling) and additive to avoided mortality from reduced emissions**

SCENARIO 2: Near 100% ϟ

Total benefits for People of Color + Hispanic

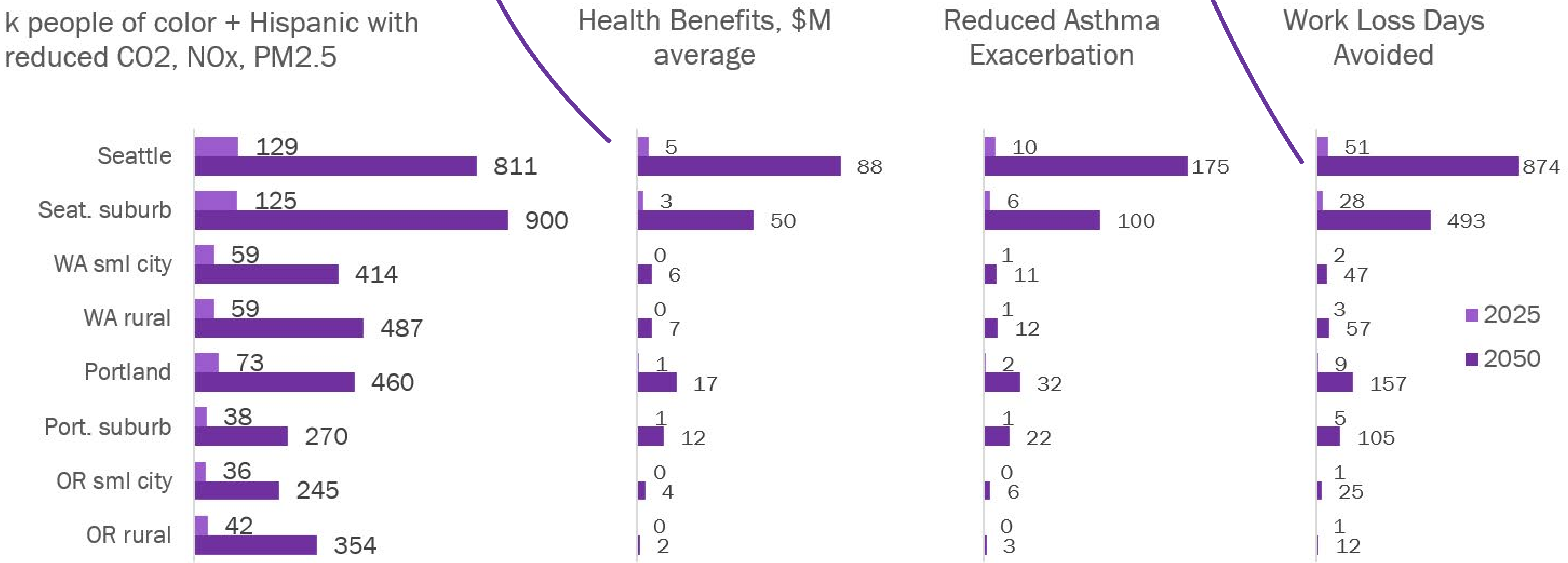
These values presented are minimum values, as benefits may occur more proportionally to vulnerable communities.



15k fewer than VMT + electrification scenario by 2050

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

874 work loss days avoided
(Seattle)



SCENARIO 2: Near 100% ⚡

Total benefits for low-income communities

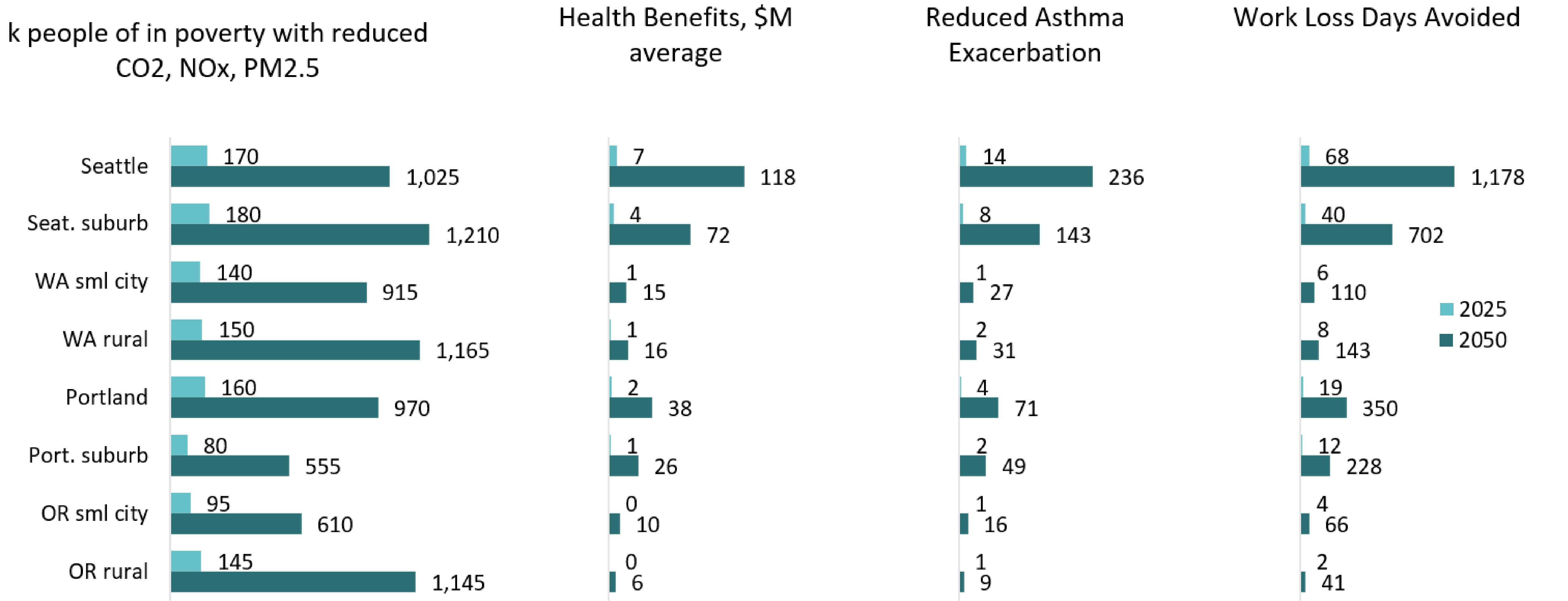
These values presented are minimum values, as benefits may occur more proportionally to vulnerable communities.

15k less than VMT + electrification scenario by 2050

Roughly 0.5-1 million people benefit in almost every region

185% Poverty level

80% AMI



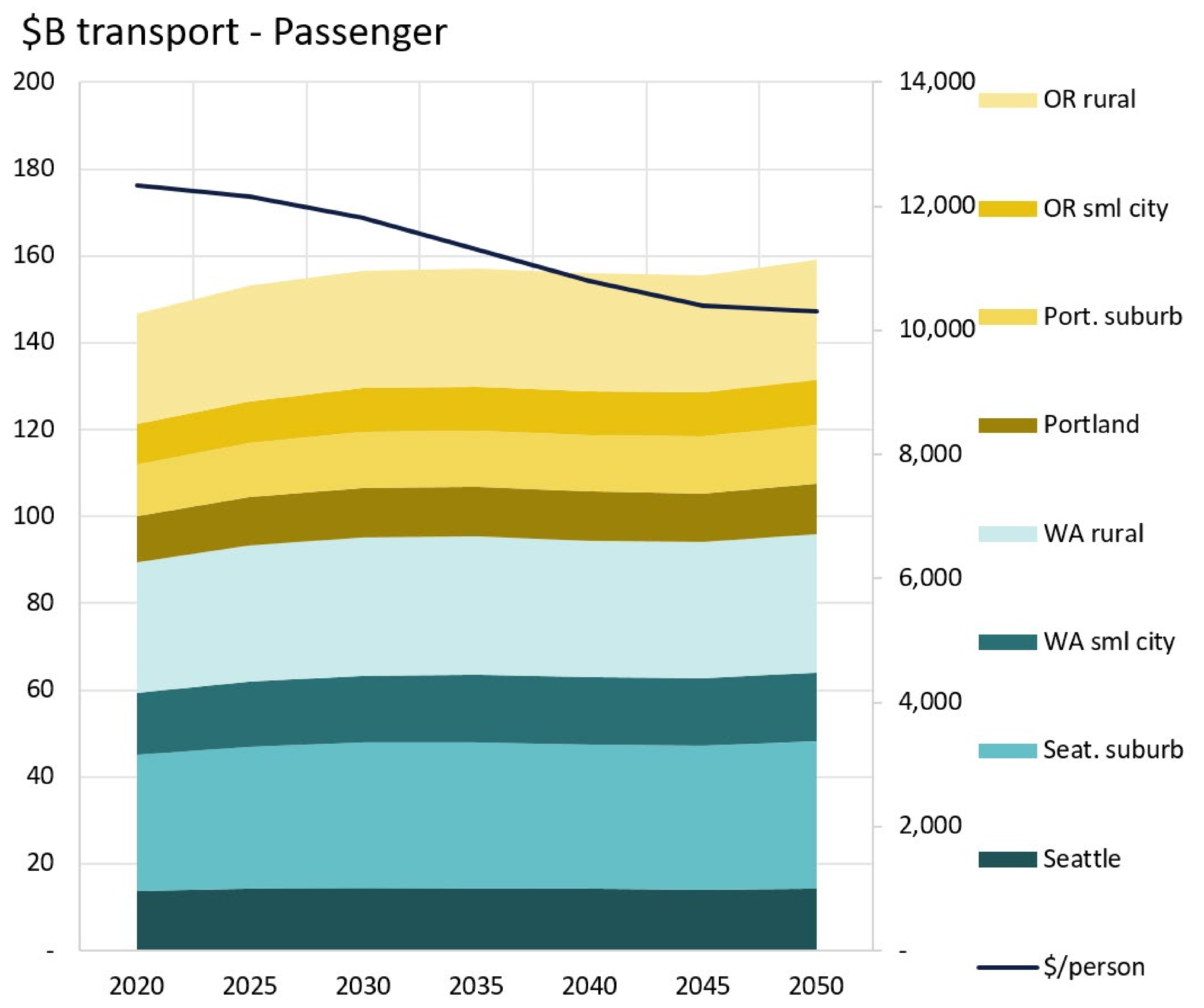
SCENARIO 2: Near 100%

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



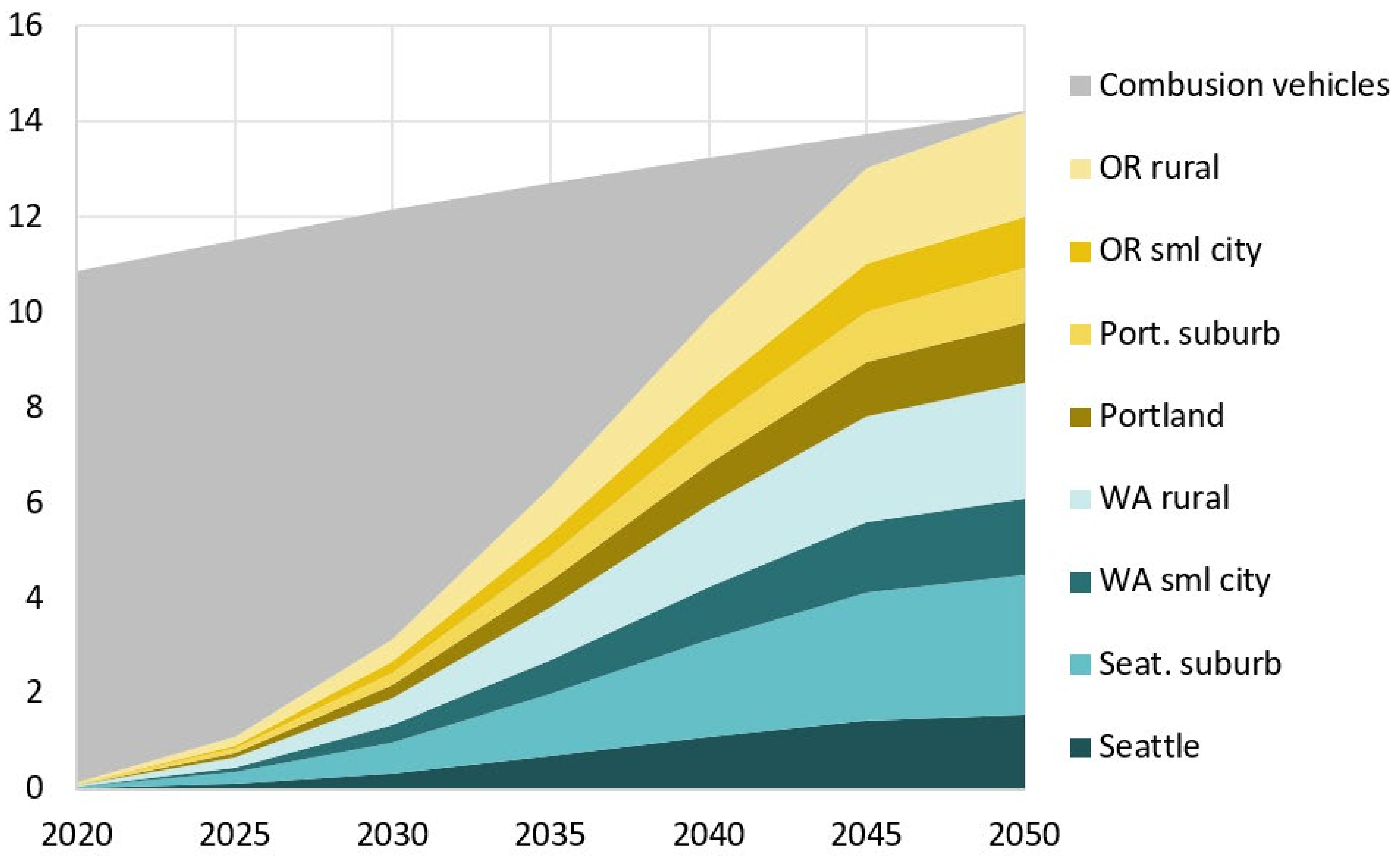
SCENARIO 2: Near 100% ⚡

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.

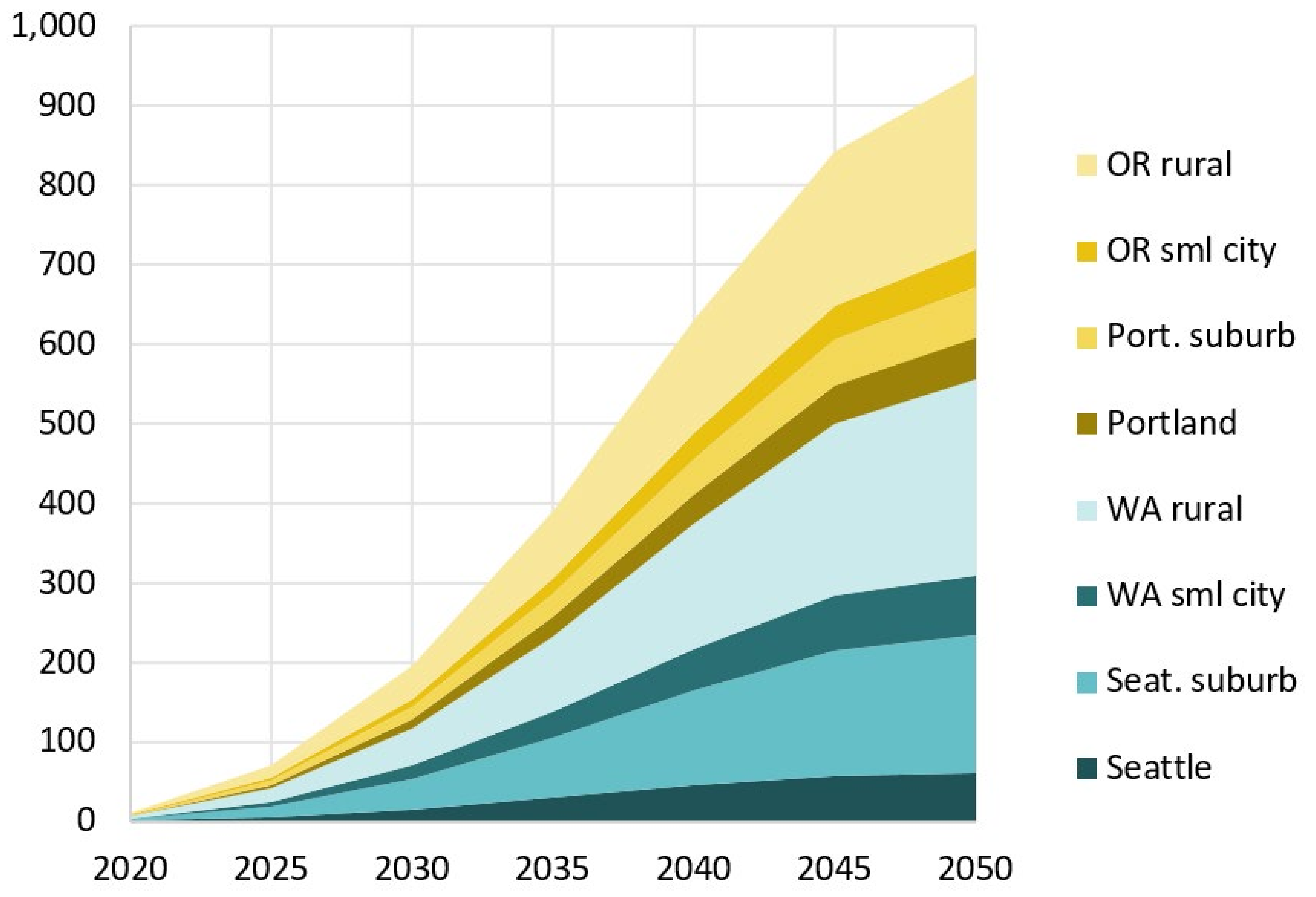
Vehicles

Today
78,000 EVs out of ~11 M vehicles
2050
Need ~14 M EVs
3.85 M more EVs 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

Society saves $3–4 B less

200 fewer lives saved annually

Personal transportation spending grows by an additional $2,600

2050 shown unless otherwise specified	Change from reduced VMT	Electrification + VMT reduction →	Electrification only
Cumulative CO_2 emissions 2020-2050	40 Mt more	515 Mt	555 Mt
Social cost of carbon, 2020-2050	$3 B more	$37 B	$40 B
Electrical power need	11 TWh more	42 TWh	53 TWh
Chargers	190 k more	750 k	940 k
$ for chargers (cumulative, low-high range)	$300-700 M more	$1.2-2.4 B	$1.6-3.2 B
Annual crash fatalities in 2050 (2030)	205 (42) more	874 (863)	1,070 (904)
Electric vehicles	3.8 M more	10.4 M	14.2
People walking, biking, or micro-mobility	250k fewer	700k	450k
People using buses	1 M fewer	2 M	1 M
Annual public road (no transit) spending in 2050 (2030)	$2.1 ($0.5) B more	$7.4 ($7.3) B	$9.5 ($7.8) B
Annual transit expenditures* in 2050 (2030)	$2.5 ($1.5) B less	$7.6 ($5.6) B	$5.1 ($4.1) B
Annual per person transport spending in 2050 (2030)	$2,600 ($1,000) more	$7,700 ($10,800)	$10,300 ($11,800)**
Total annual personal transport spending in 2050 (2030)	$40 ($14) B more	$119 ($143) B	$159 ($157) B

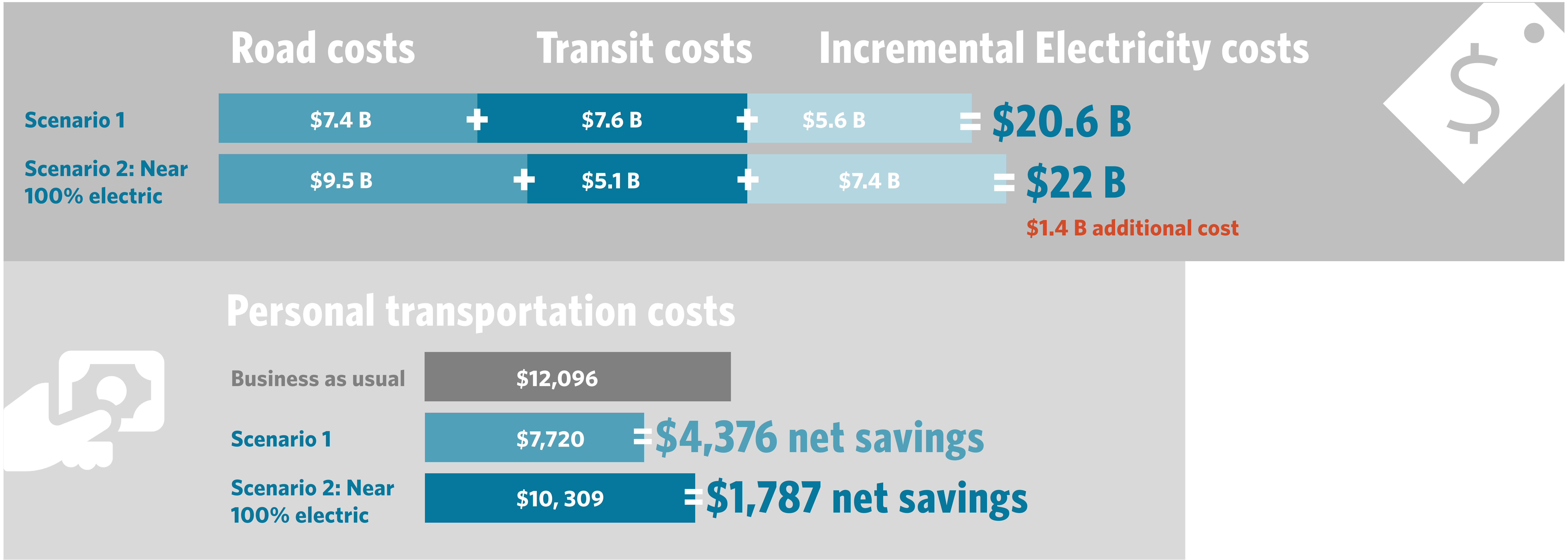
*Includes fare recovery

**Down from $12,350 in 2020

SCENARIO 2: Near 100%

Annual Direct Costs

Annual direct costs for electrification only scenario are $1.4 B more than VMT reduction + electrification



SCENARIO 3: NOT OPTIMAL

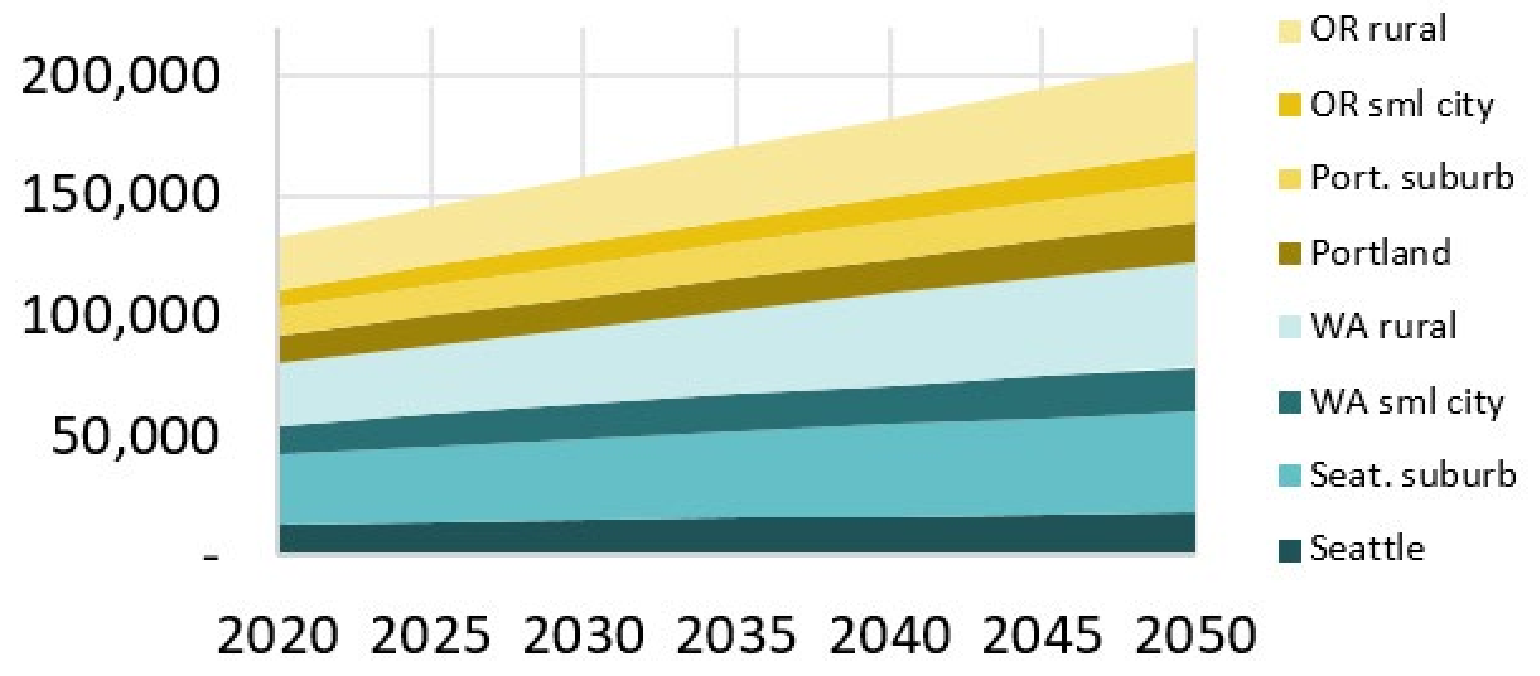
Increase in Vehicle Miles Traveled + Electrification

WHAT HAPPENS IF EVERYONE DRIVES ELECTRIC, BUT DRIVES MORE MILES?

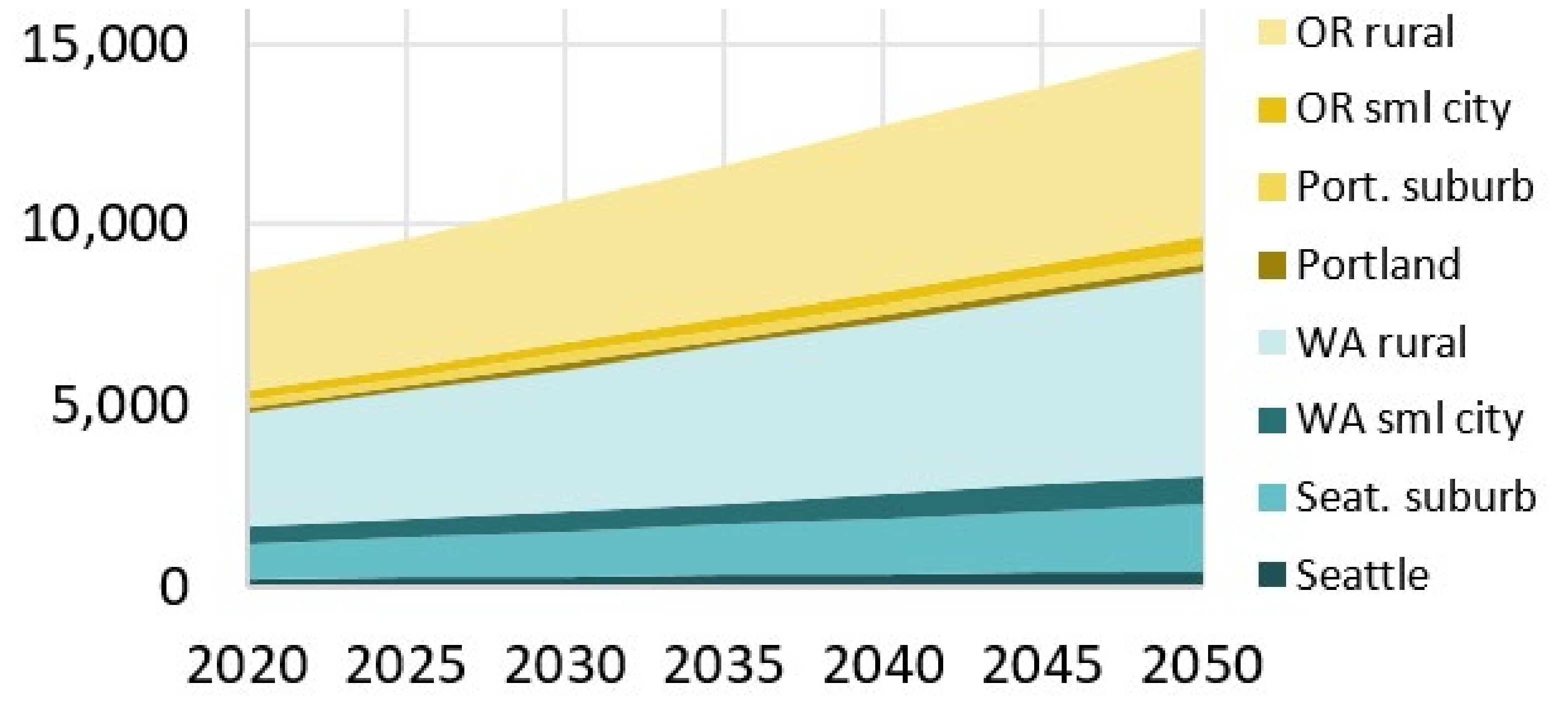
It's possible to achieve full decarbonization, but this scenario is ***expensive*** and not ideal.

Scenario 3 relative to business as usual.

Passenger Miles Traveled (M): 35% (rural) to 10% (urban)% increase in 2050



Freight miles: 12% increase

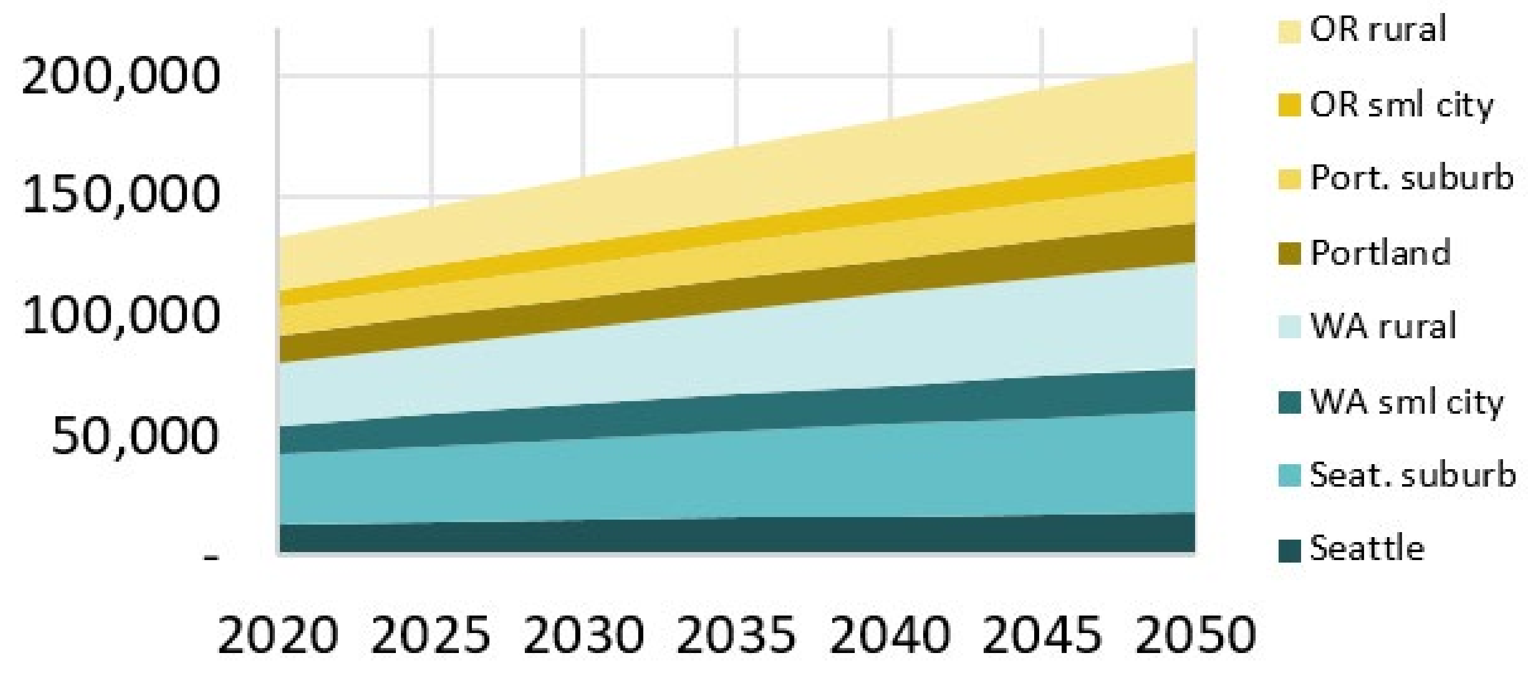


WHAT CAUSES US TO DRIVE MORE?

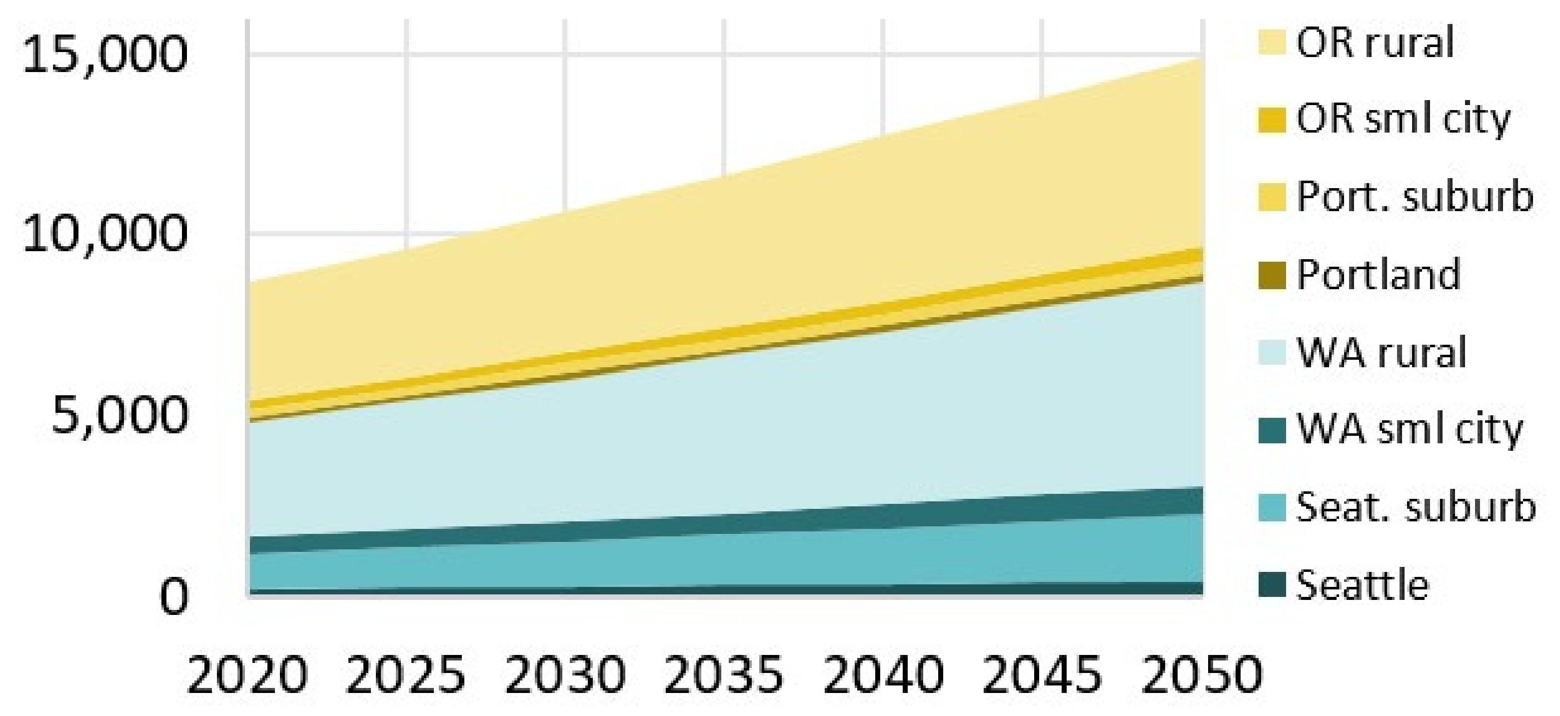
Poor land use decisions that increase sprawl and cause more driving, economic circumstances leading to more freight delivery, and potentially automation.

Scenario 3 relative to business as usual.

Passenger Miles Traveled (M): 35% (rural) to 10% (urban)% increase in 2050



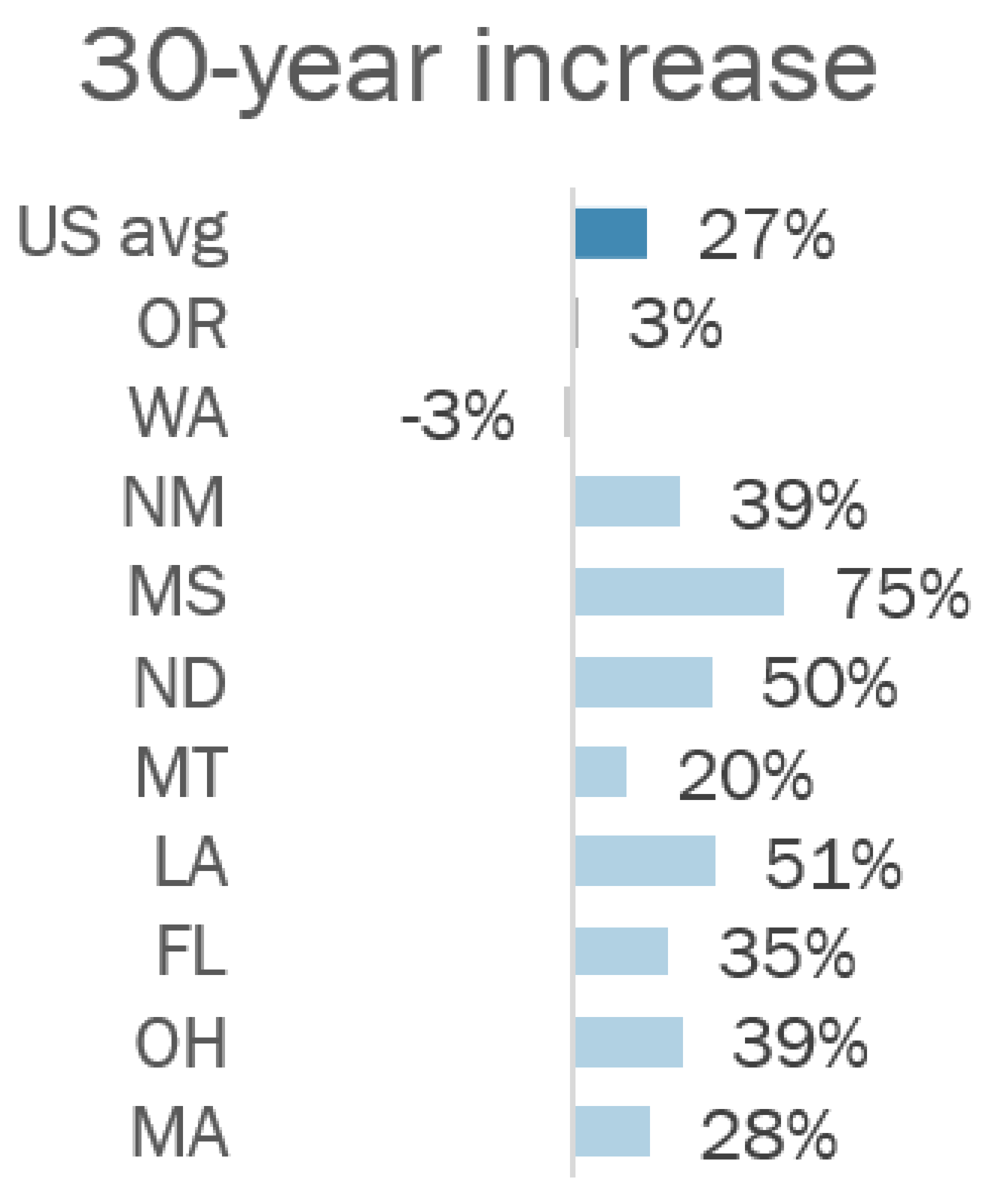
Freight miles: 12% increase

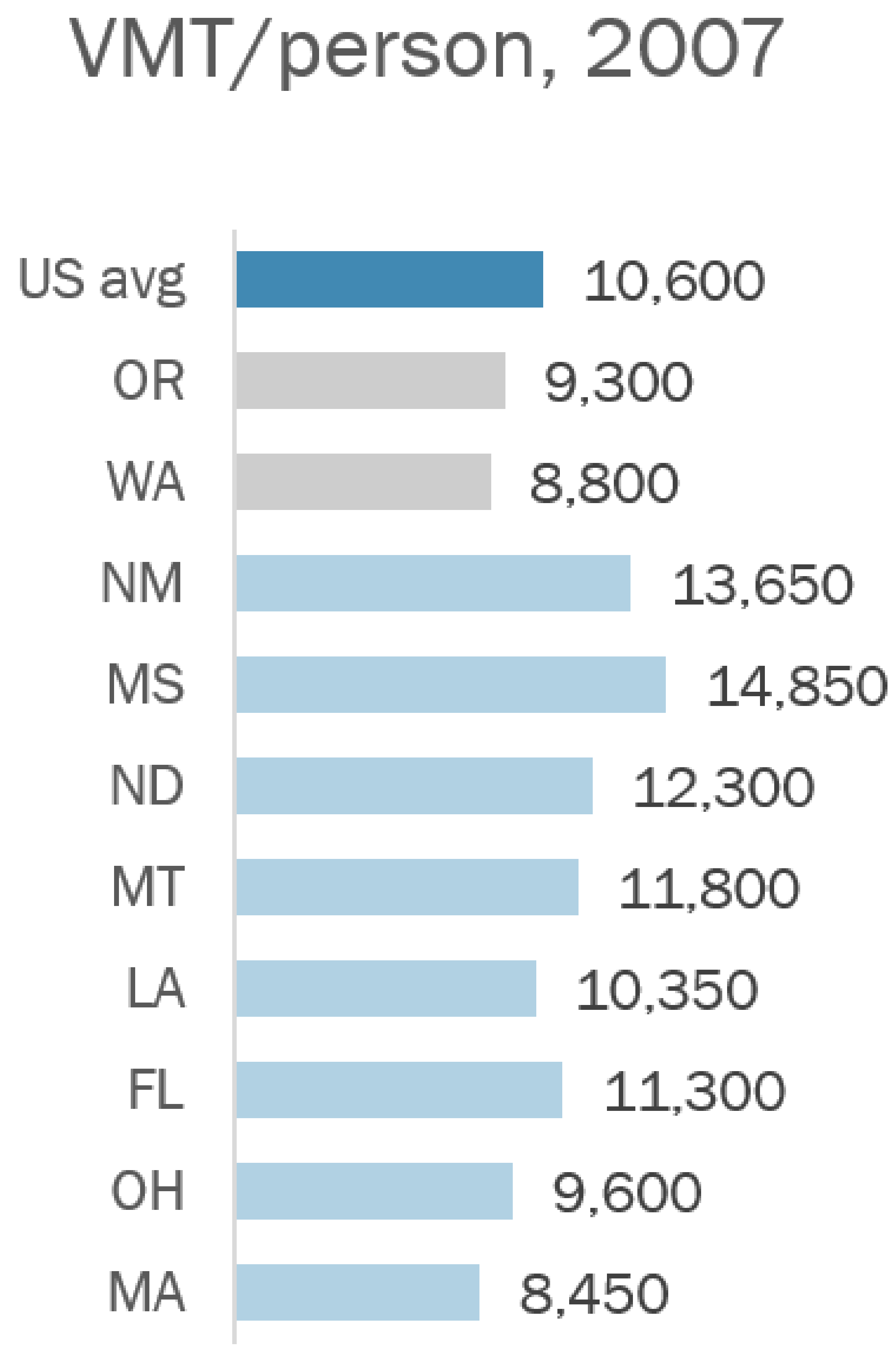


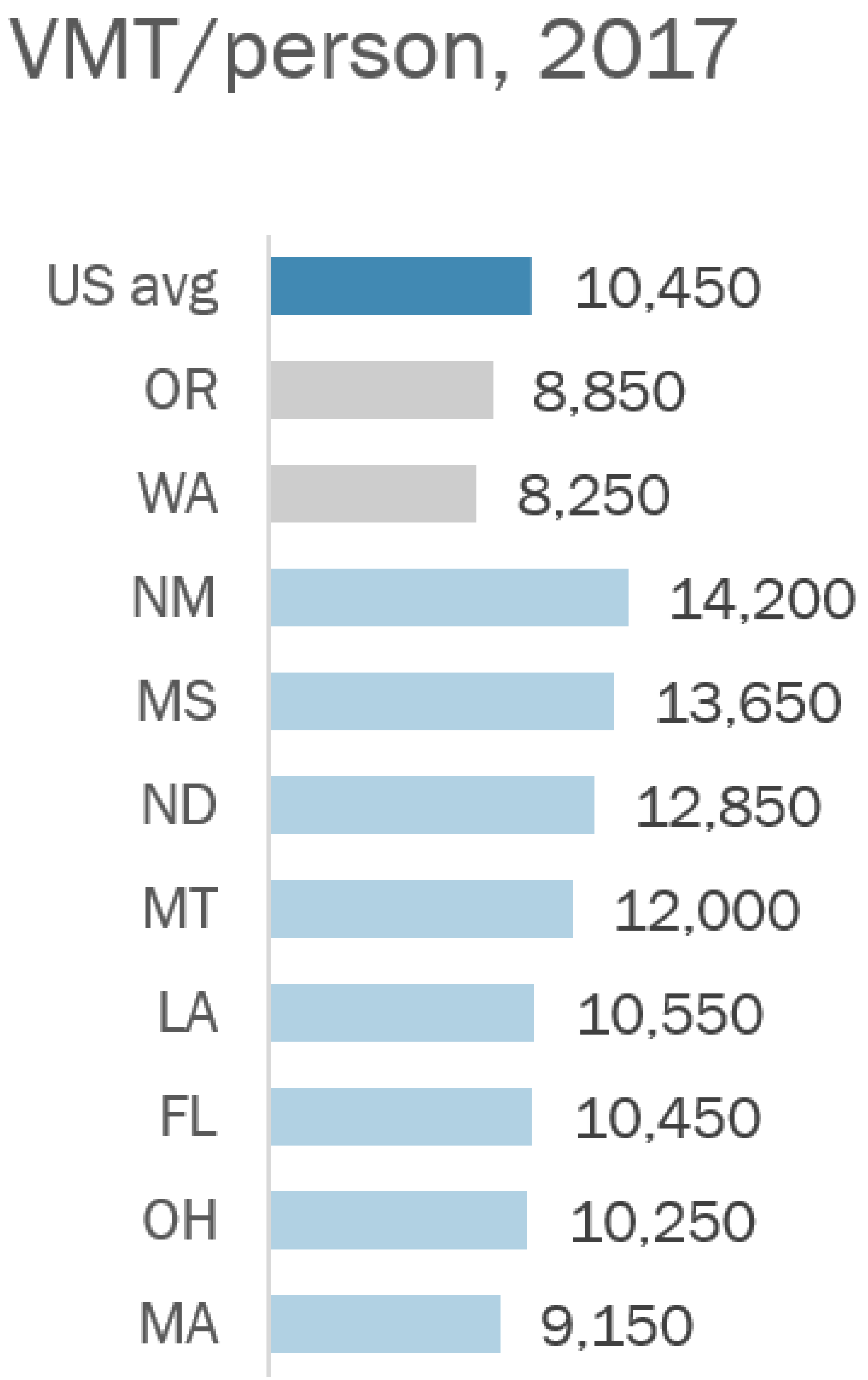
SCENARIO 3: ↑ VMT + ⚡

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

	Passenger Miles Traveled Increase	Equivalent to
Urban	10%	
Suburban	10%	
Small city	15%	
Rural*	35%	North Dakota travel today, or change in travel in Florida or Ohio over 30 years

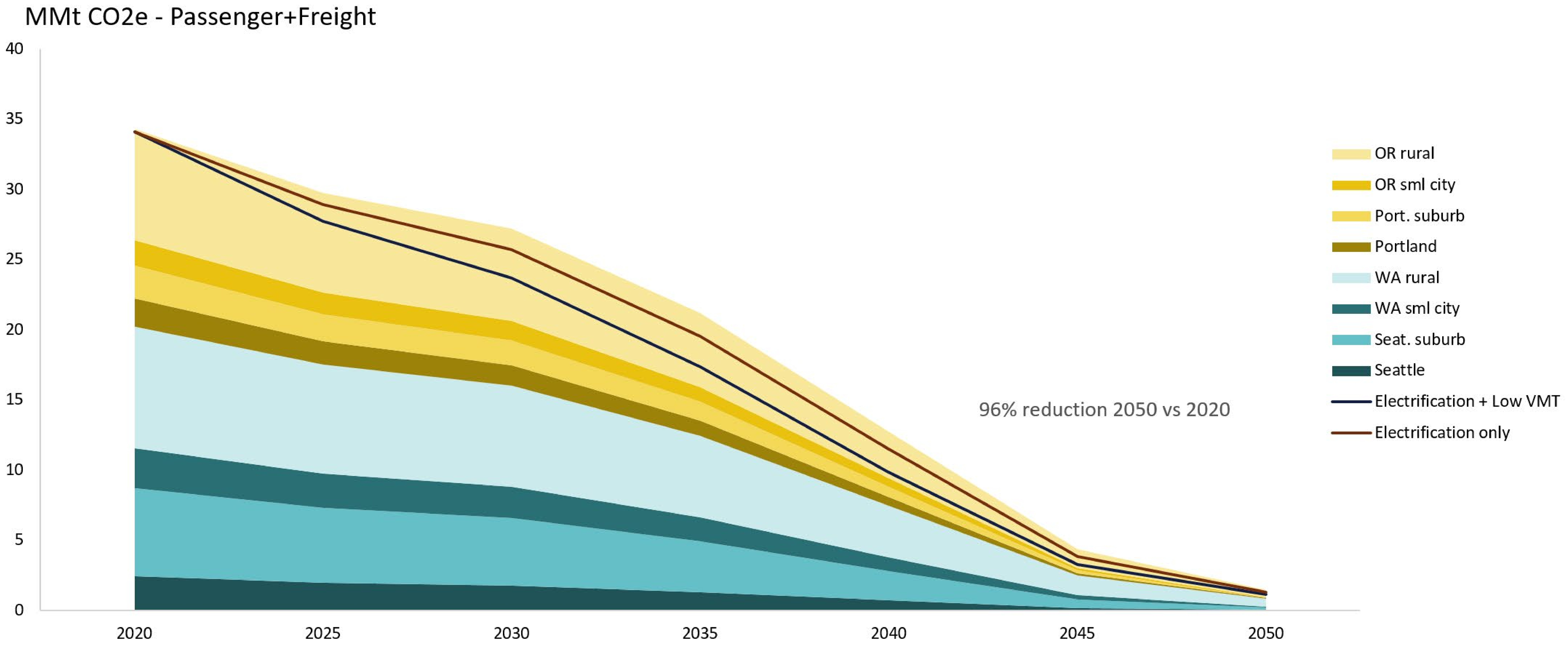
	Miles Traveled Increase	References
Freight	12%	This represents an economic growth scenario (value from Freight Analysis Framework)
State-wide	22% PMT increase	21% VMT increase (personal & freight)

* Rural VMT growing faster than urban, https://www.psrc.org/sites/default/files/trend-vmt-201911.pdf

SCENARIO 3: ⬆ 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: ↑ VMT + ⚡

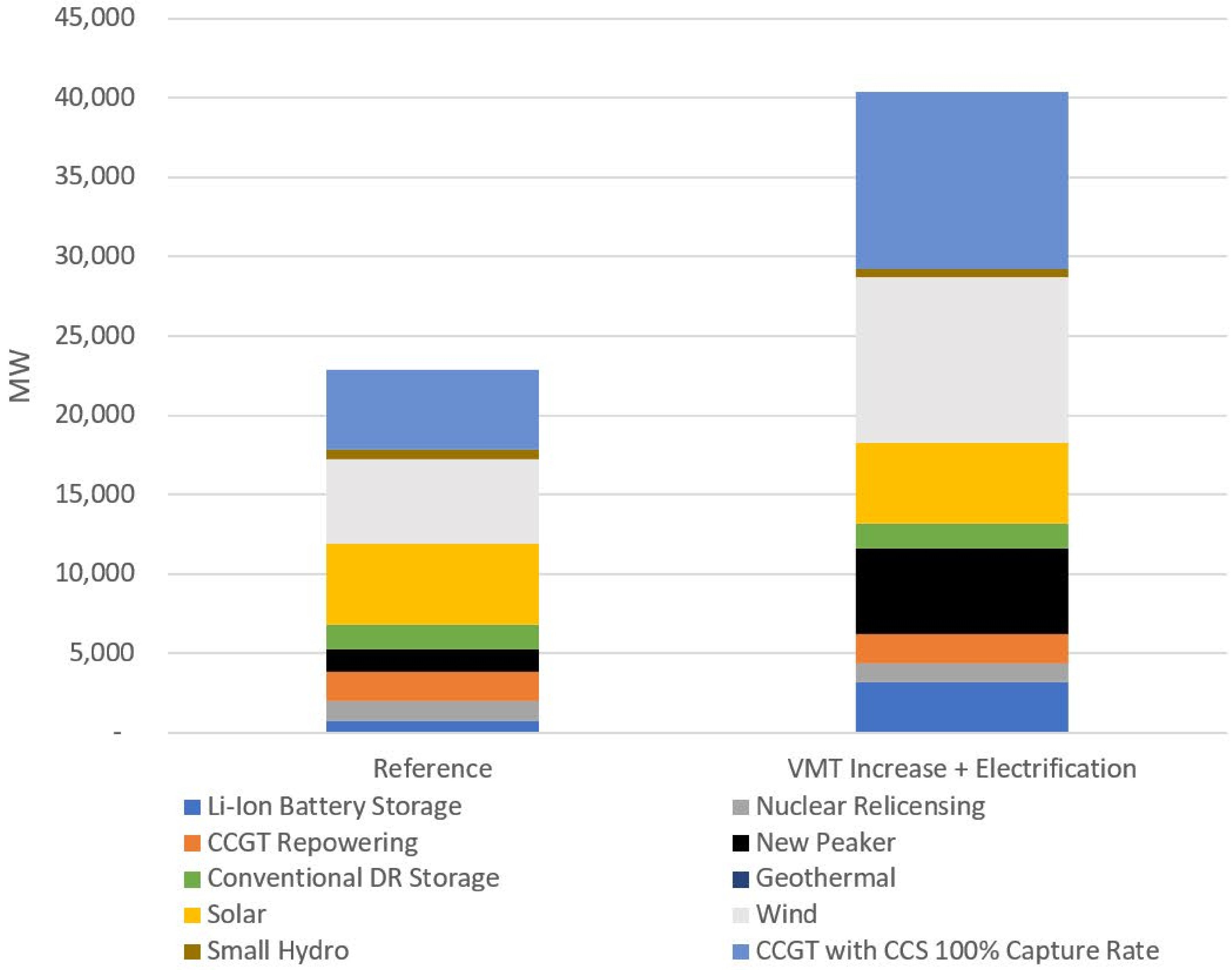
ELECTRICITY BY THE NUMBERS

System cost	$18.89 B	+	$8.85 B	=	$27.74 B

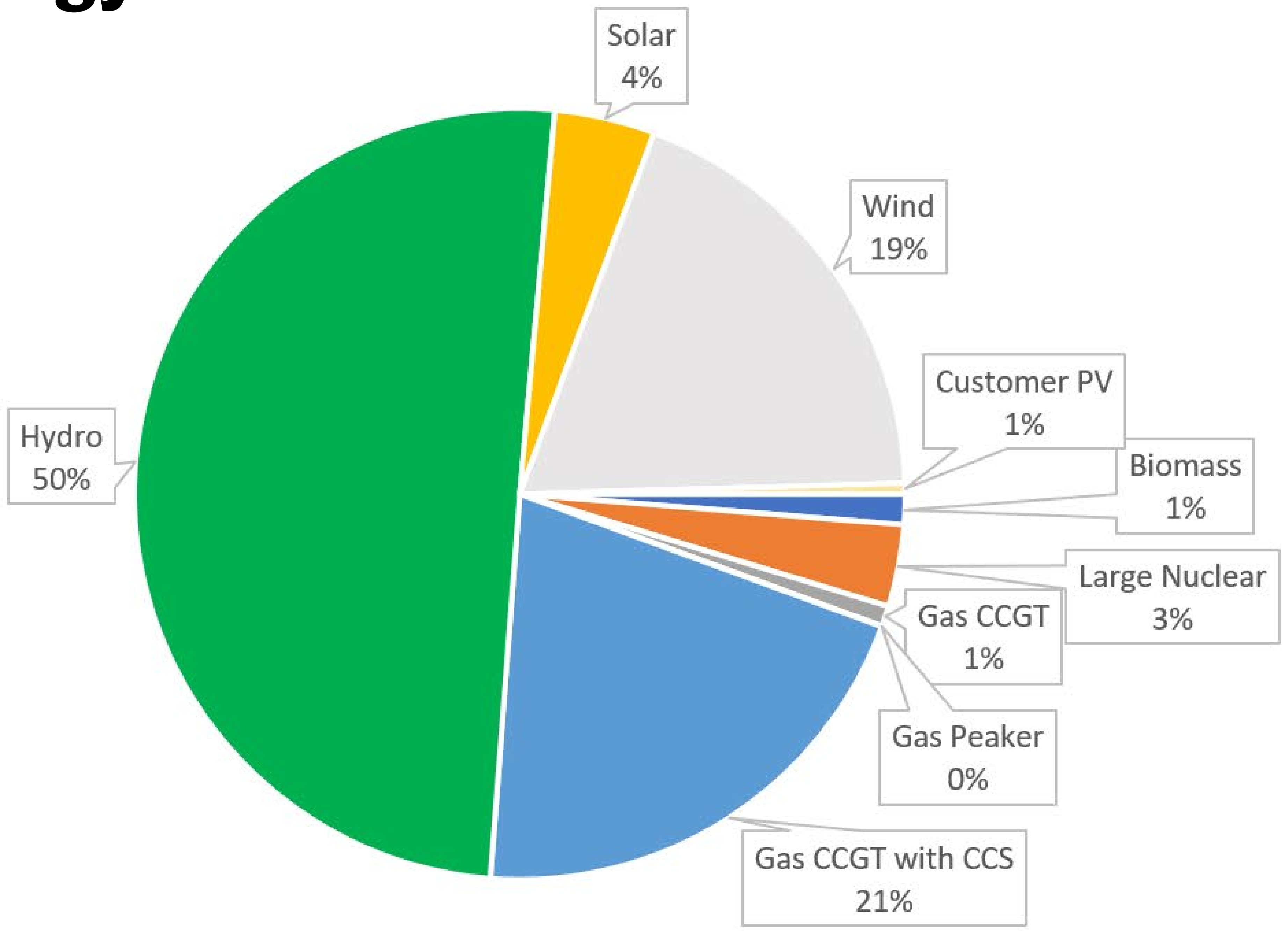
Total load (TWh) 198 **+59**

Peak Capacity (GW) 36 **+9.9**

Resource Builds 2050



Energy Mix



SCENARIO 3: ↑ VMT + ⚡

* Additional avoided mortality from reduced crashes is independently modeled (not part of the COBRA modeling) and additive to avoided mortality from reduced emissions

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.

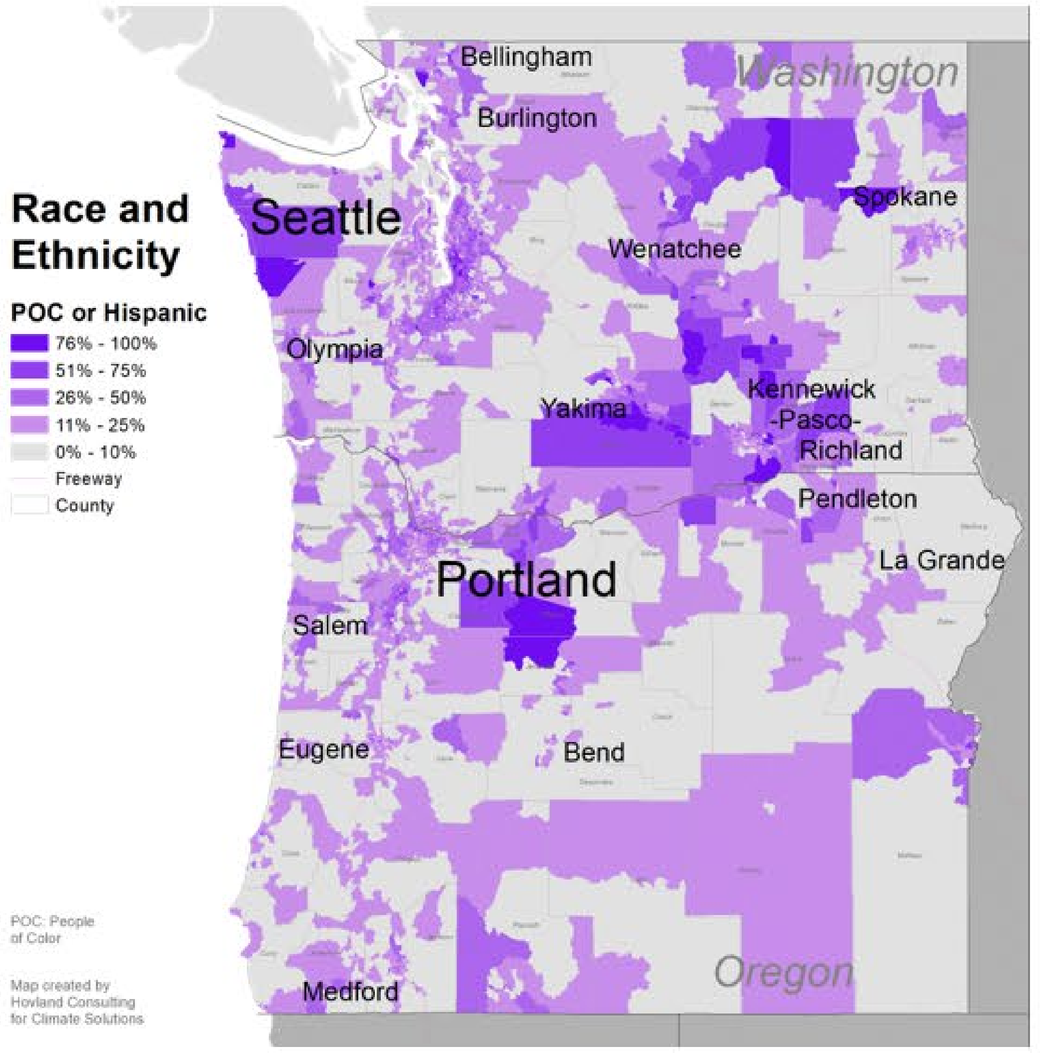
	Change with increased VMT, 2050	Electrification + VMT reduction, 2050 (2025)	Electrification + VMT increase, 2050 (2025)
$ Total Health Benefits (low-high)	~similar	$626 – $278 M ($68 – $30 M)	$620 – $274 M ($52 – $22 M)
$ Hospital Admits reduced, All Respiratory	~similar	$186 k ($20 k)	$184 k ($15 k)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

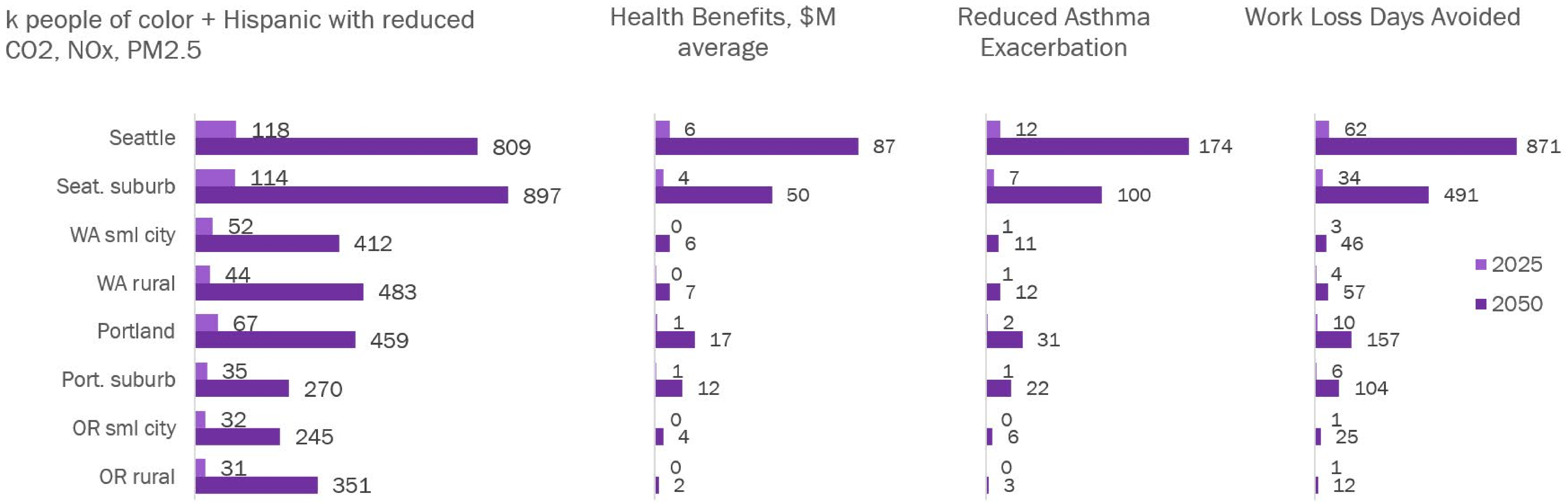
SCENARIO 3: ⬆ VMT + ⚡

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



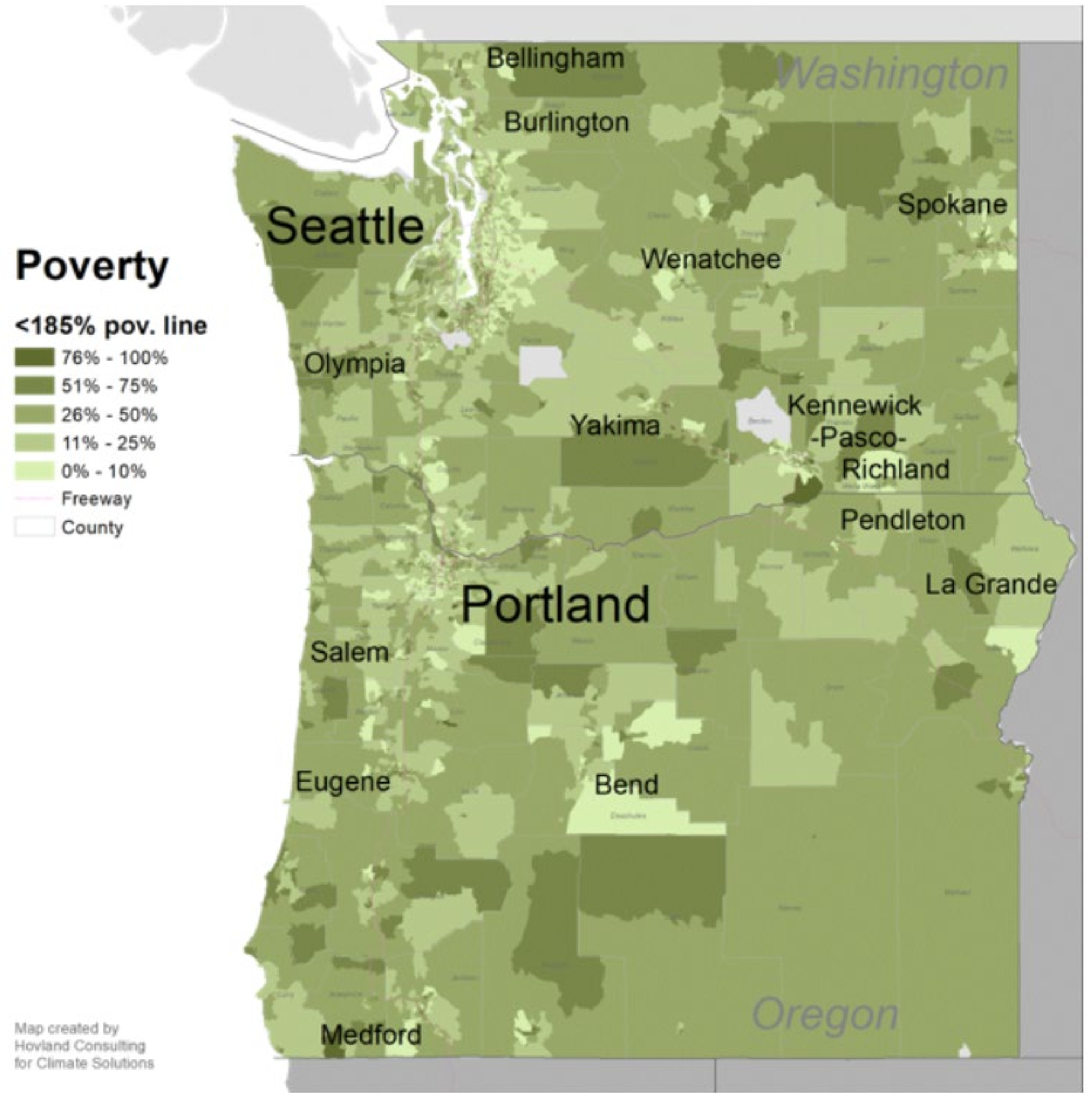


	k people of color + Hispanic with reduced CO2, NOx, PM2.5 (2025)	(2050)	Health Benefits, $M average (2025)	(2050)	Reduced Asthma Exacerbation (2025)	(2050)	Work Loss Days Avoided (2025)	(2050)
Seattle	118	809	6	87	12	174	62	871
Seat. suburb	114	897	4	50	7	100	34	491
WA sml city	52	412	0	6	1	11	3	46
WA rural	44	483	0	7	1	12	4	57
Portland	67	459	1	17	2	31	10	157
Port. suburb	35	270	1	12	1	22	6	104
OR sml city	32	245	0	4	0	6	1	25
OR rural	31	351	0	2	0	3	1	12

SCENARIO 3: ↑ VMT + ⚡

Total benefits for low-income communities

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

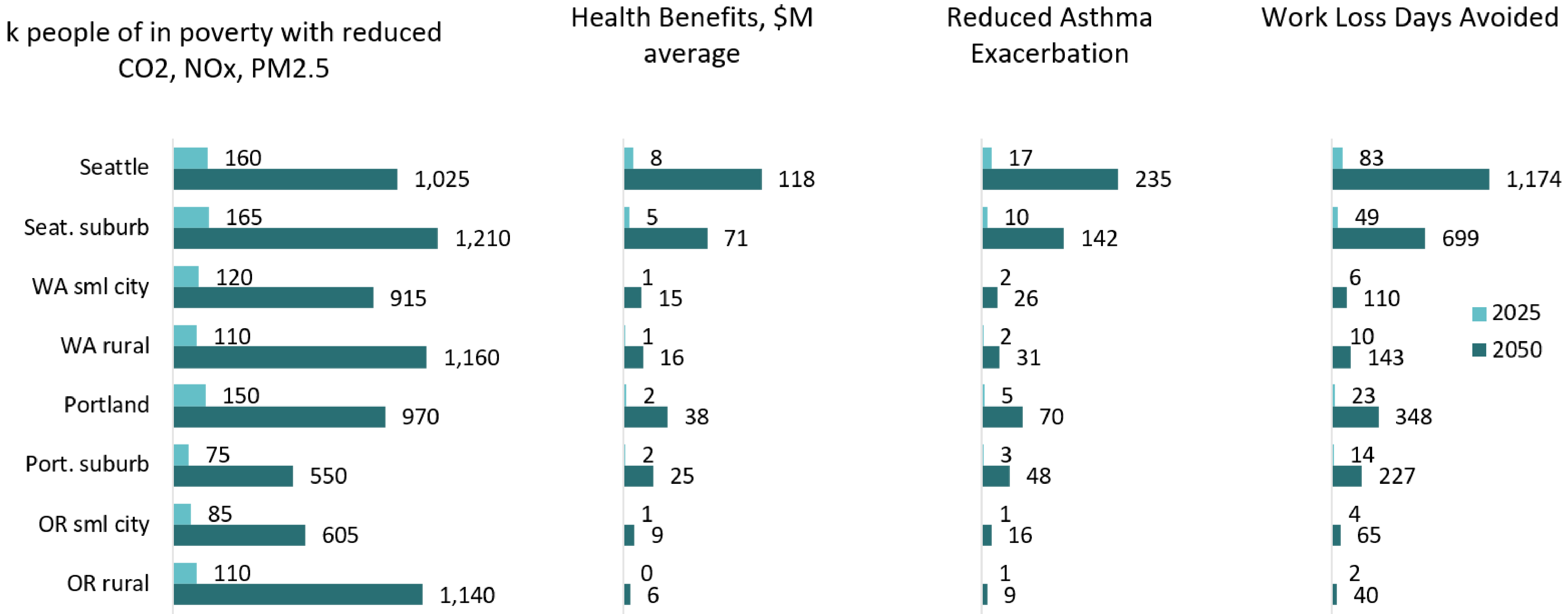


40k fewer than Scenario 1 (VMT reduction + electrification) by 2050

Roughly 0.5-1 million people benefit in almost every region

185% Poverty level

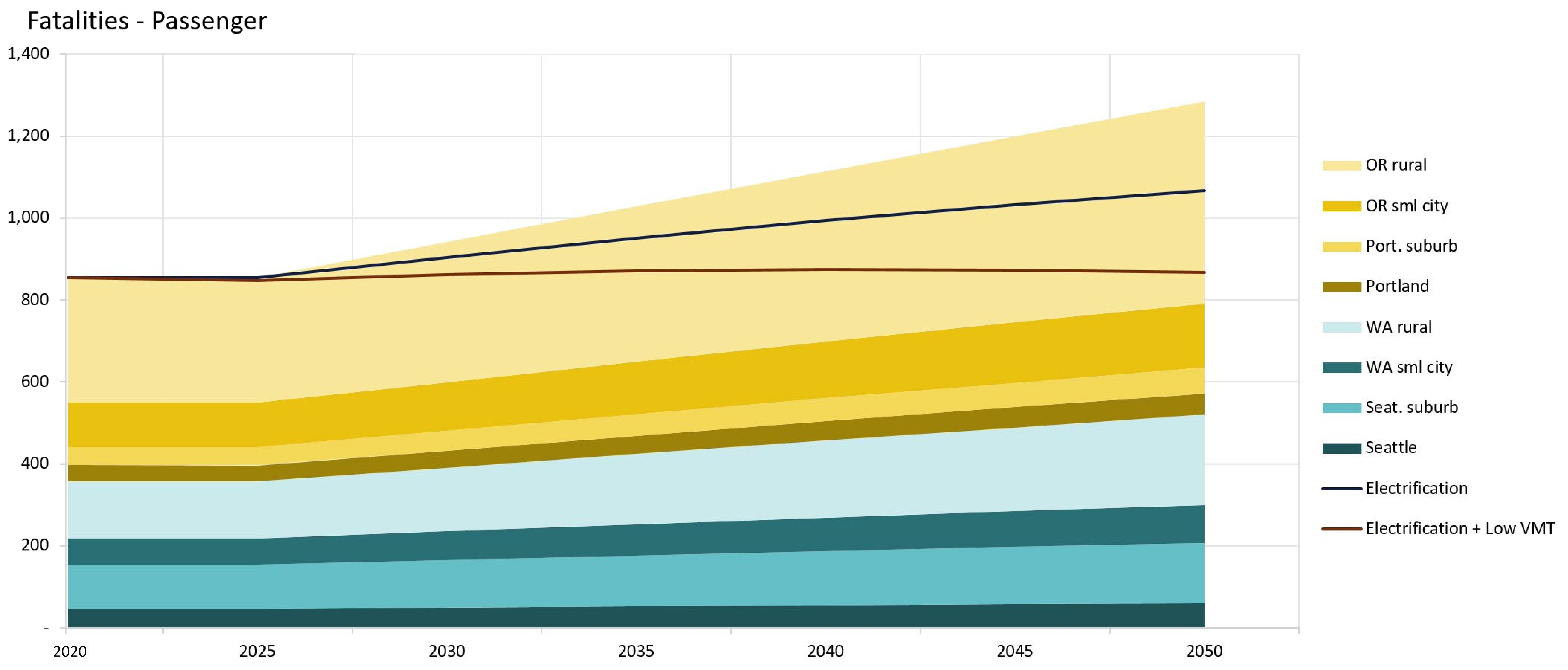
80% AMI



SCENARIO 3: ⬆ VMT + ⚡

Crash Fatalities

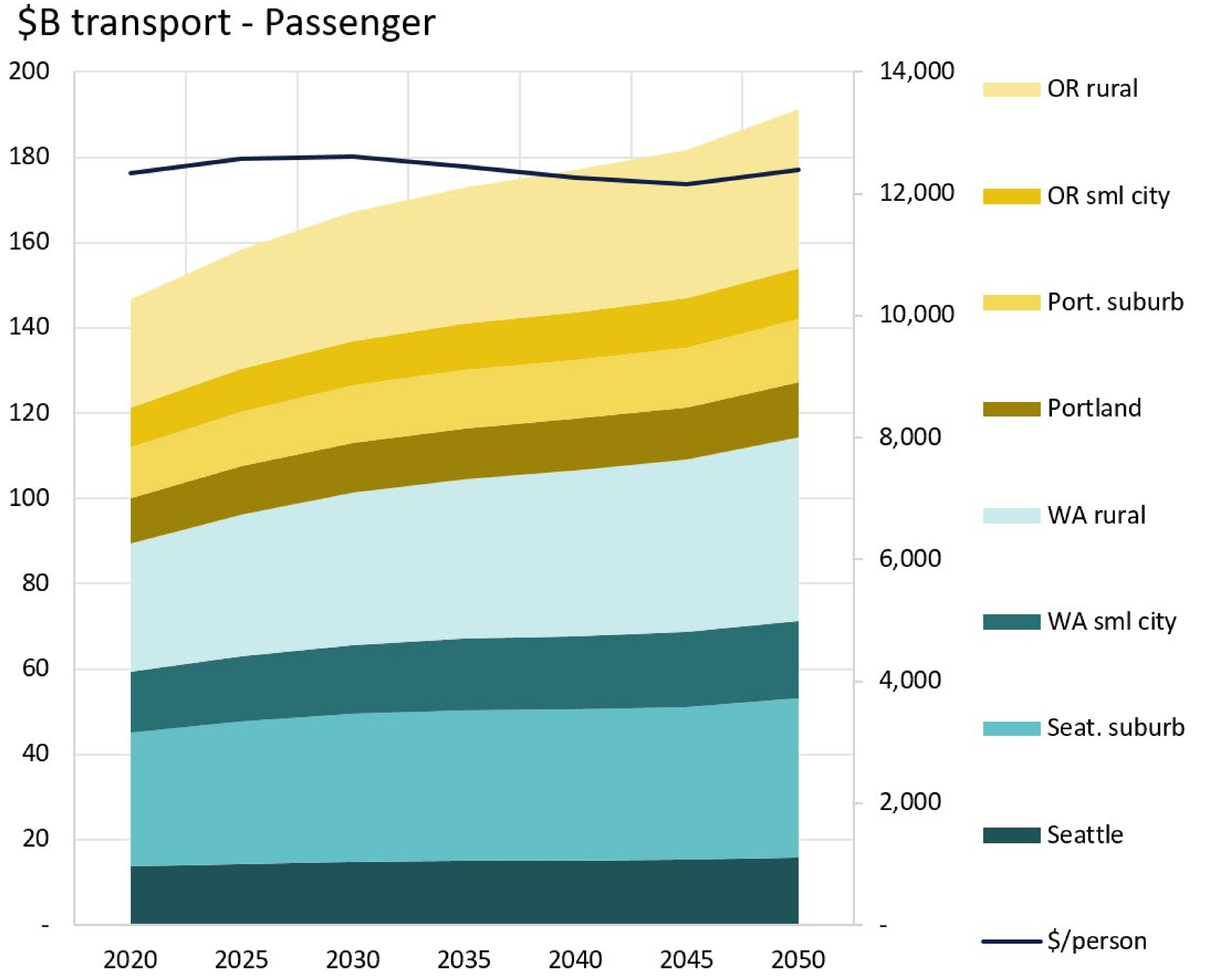
216 lives are lost in 2050 (and 37 in 2030) compared to BAU VMT. Even more lives (425 in 2050) are lost compared to the low VMT scenario. Crash fatalities are especially high in rural OR.



SCENARIO 3: ↑ VMT + ⚡

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.



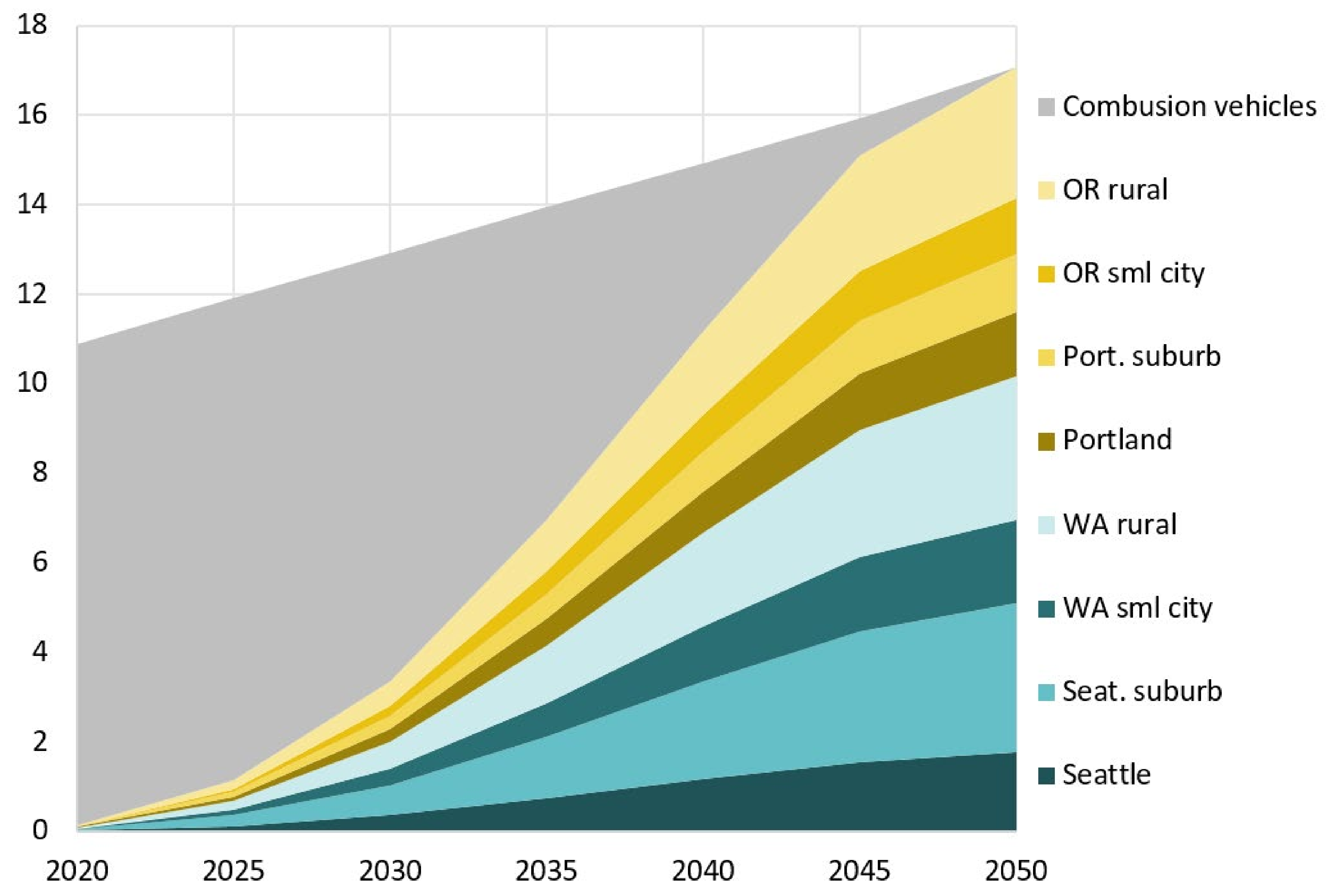
SCENARIO 3: ⬆ VMT + ⚡

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

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

SCENARIO 3: ↑ VMT + ⚡

Annual Direct Costs

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

	Road costs		Transit costs		Incremental Electricity costs		Total
Scenario 1	$7.4 B	+	$7.6 B	+	$5.6 B	=	$20.6 B
Scenario 3: VMT Increase + Electrification	$10.9 B	+	$4.6 B	+	$8.9 B	=	$24.4 B $3.8 B additional cost

Personal transportation costs

Business as usual	$12,096	
Scenario 1	$7,720	= $4,376 net savings
Scenario 3: VMT Increase + Electrification	$12,392	= $296 additional cost (vs. BAU)

SCENARIO 3: ↑ VMT + ⚡

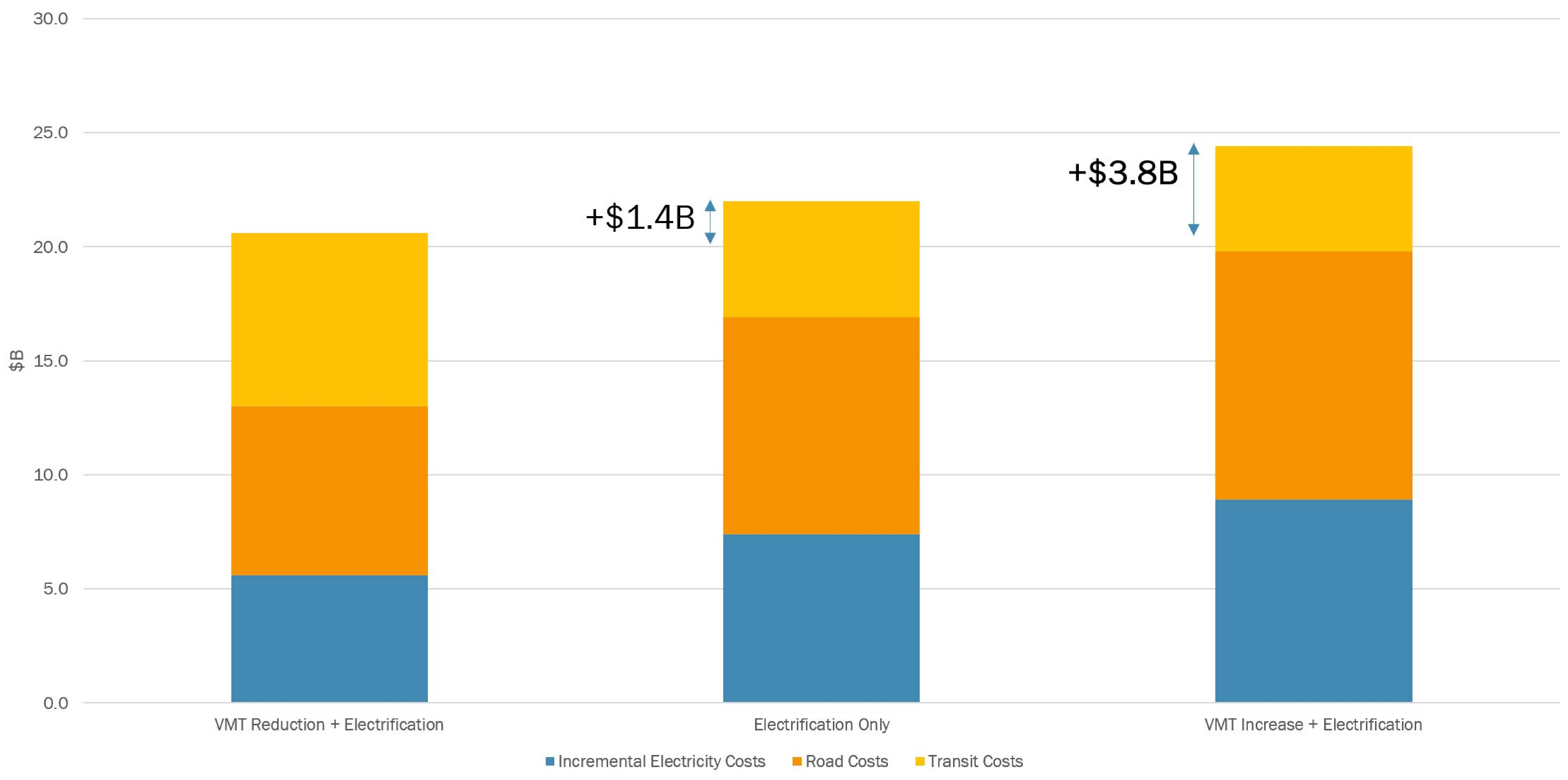
Comparison: Increased VMT

Societal costs significantly increase

2050 shown unless otherwise specified	Change with increased VMT	Electrification + VMT reduction	➡ EV + high VMT (esp. rural)
Cumulative CO_2 emissions 2020-2050	**70 Mt more**	515 Mt	585 Mt
Social cost of carbon, 2020-2050	**$6 B more**	$37 B	$43 B
Electrical power need	**20 TWh more**	42 TWh	62 TWh
Chargers	**350 k more**	750 k	1,100 k
$ for chargers (cumulative, low-high range)	**$0.6-1.2 B more**	$1.2-2.4 B	$1.8-3.6 B
Annual crash fatalities in 2050 (2030)	**411 (77) more**	874 (863)	1,285 (940)
Electric vehicles	**6.7 M more**	10.4 M	17.1 M
People walking, biking, or micro-mobility	**250k fewer**	700k	450 k
People using buses	**1.2 M fewer**	2 M	0.8 M
Annual public road (no transit) spending in 2050 (2030)	**$3.5 ($.8) B more**	$7.4 ($7.3) B	$10.9 ($8.1) B
Annual transit expenditures* in 2050 (2030)	**$3 ($1.8) B more**	$7.6 ($5.6) B	$4.6 ($3.8) B
Annual per person transport spending in 2050 (2030)	**~$4,700 ($1,800) more**	~$7,700 ($10,800)	~$12,400 ($12,600)
Total annual personal transport spending in 2050 (2030)	**$72 ($24) B more**	$119 ($143) B	$191 ($167) B

SCENARIOS 1-3

Direct Costs Summary

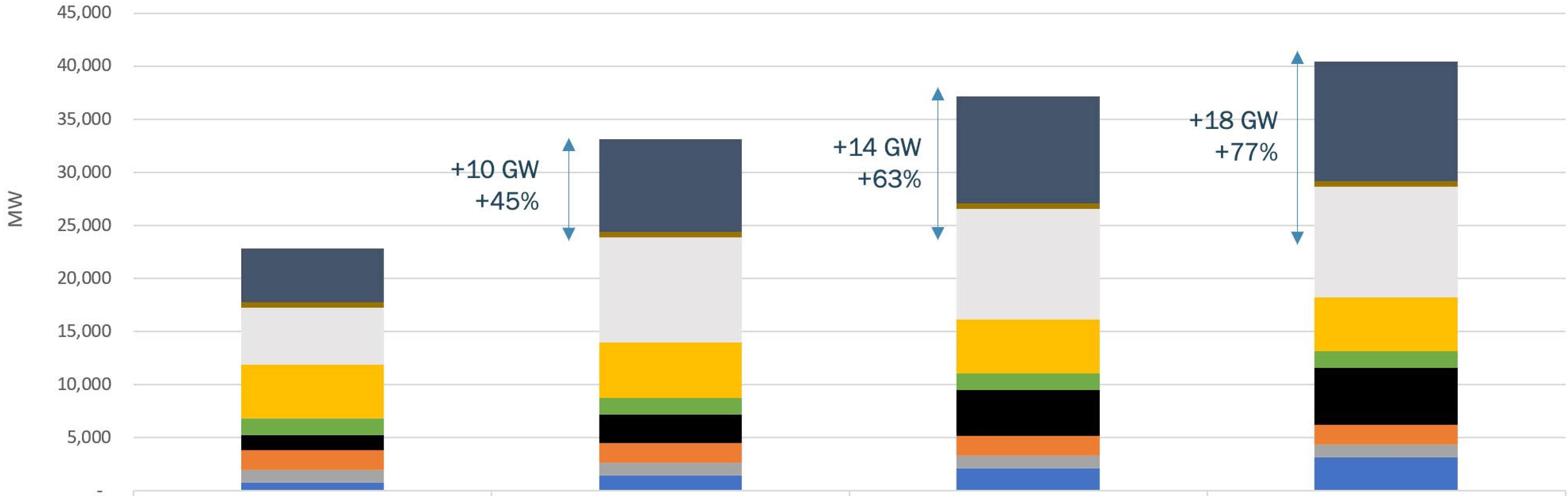


ELECTRICITY SECTOR:

Summary & Sensitivities

Load Management & SMR Resource Option

ELECTRICITY SECTOR

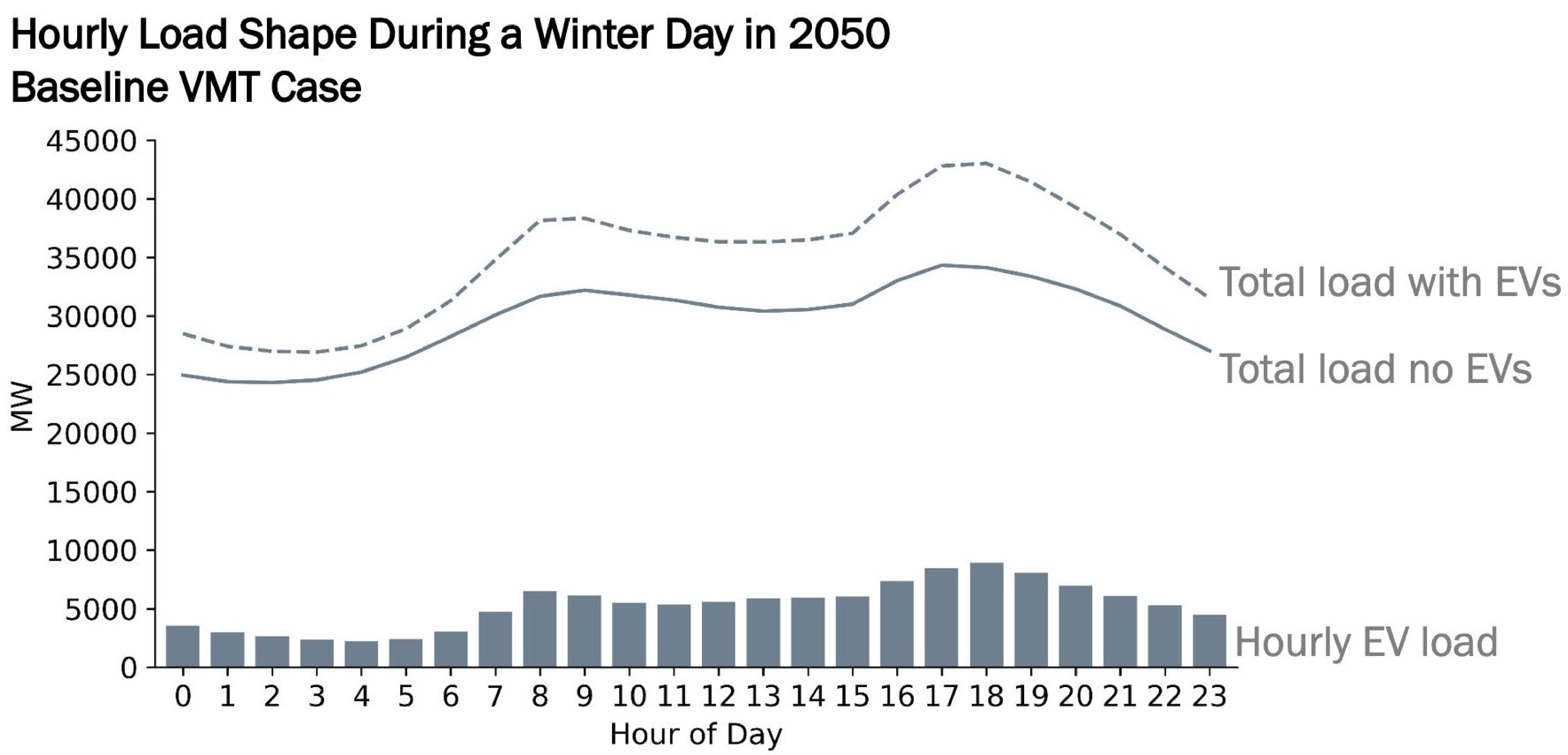


	Reference	VMT Reduction + electrification	Electrification Only	VMT Increase + Electrification
CCGT with CCS 100% Capture Rate	5,056	8,678	10,020	11,216
Small Hydro	539	539	539	539
Wind	5,348	9,936	10,430	10,430
Solar	5,104	5,196	5,104	5,104
Conventional DR Storage	1,559	1,559	1,559	1,559
New Peaker	1,427	2,691	4,329	5,357
CCGT Repowering	1,842	1,842	1,842	1,842
Nuclear Relicensing	1,207	1,207	1,207	1,207
Li-Ion Battery Storage	758	1,464	2,116	3,163

ELECTRICITY SECTOR

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



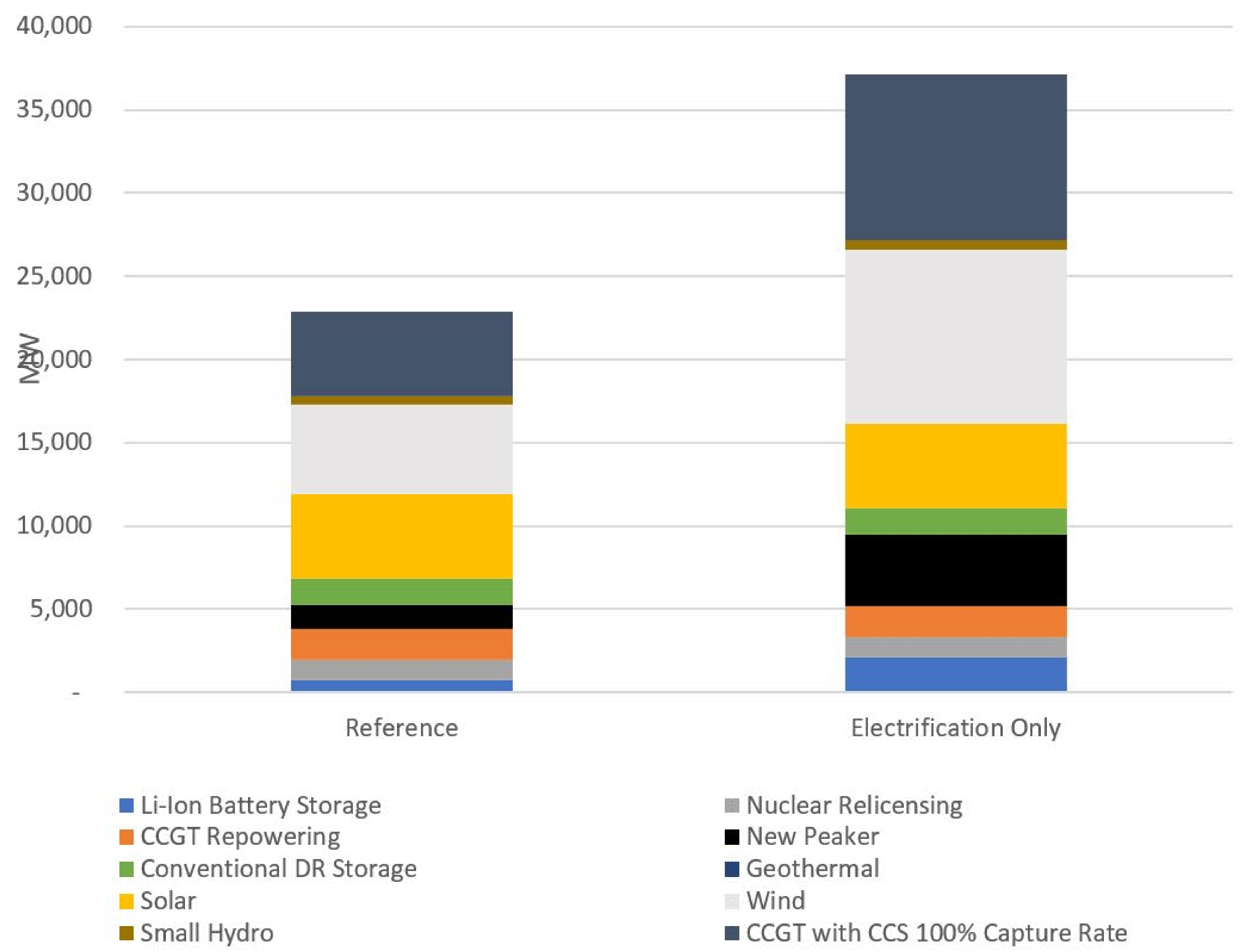
ELECTRICITY SECTOR

ELECTRICITY BY THE NUMBERS

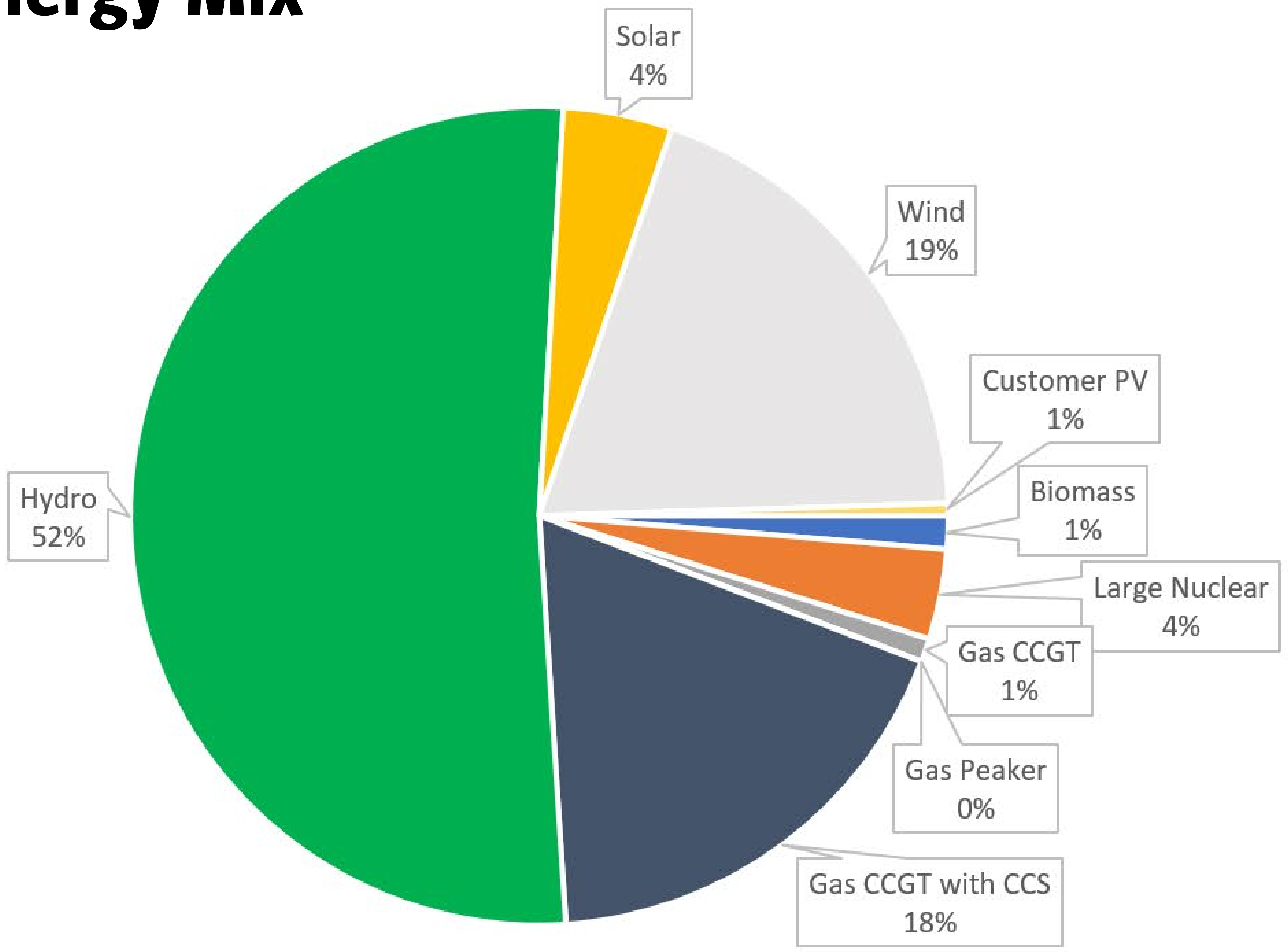
System cost $18.89 B + $7.4 B = $26.92 B

Total load (TWh) 198 +59 Peak Capacity (GW) 36 +9.7

Resource Builds 2050



Energy Mix



ELECTRICITY SECTOR

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.

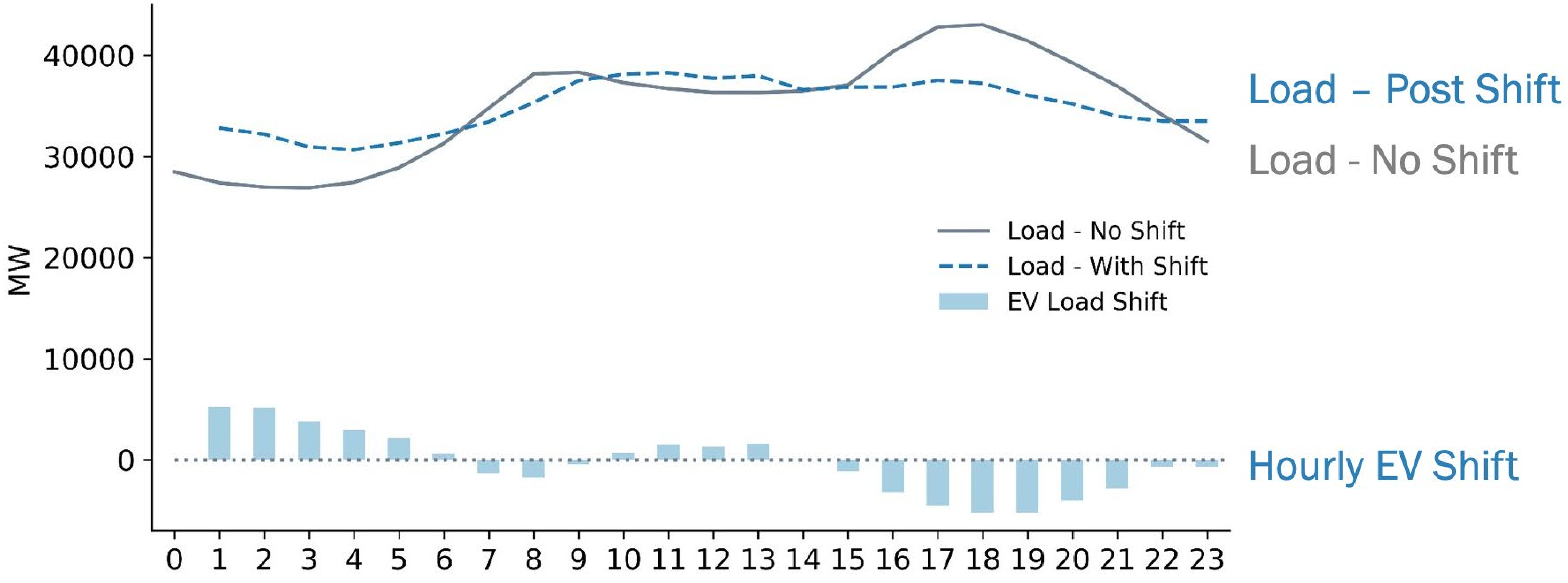
Total Load Shift (MWh/day)

94,229

Percent Load Shifted

8%

Load Shifting in RESOLVE
Baseline VMT Case



ELECTRICITY SECTOR

Electrification Only + Managed Load

ELECTRICITY BY THE NUMBERS

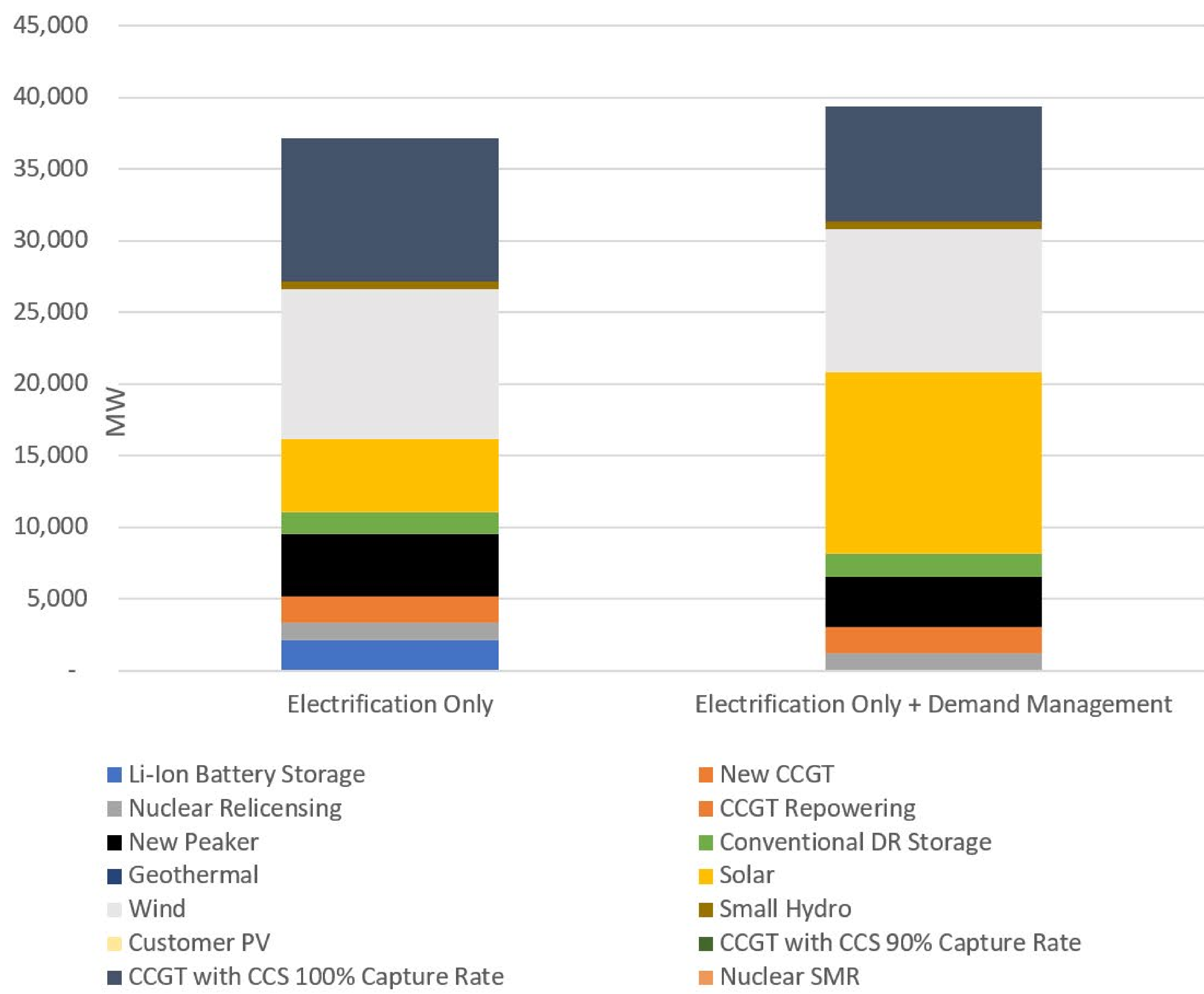
Scen 2 (100%)

System cost	$18.89 B	+ $7.4 B	+ $-0.6 B	= $26.32 B

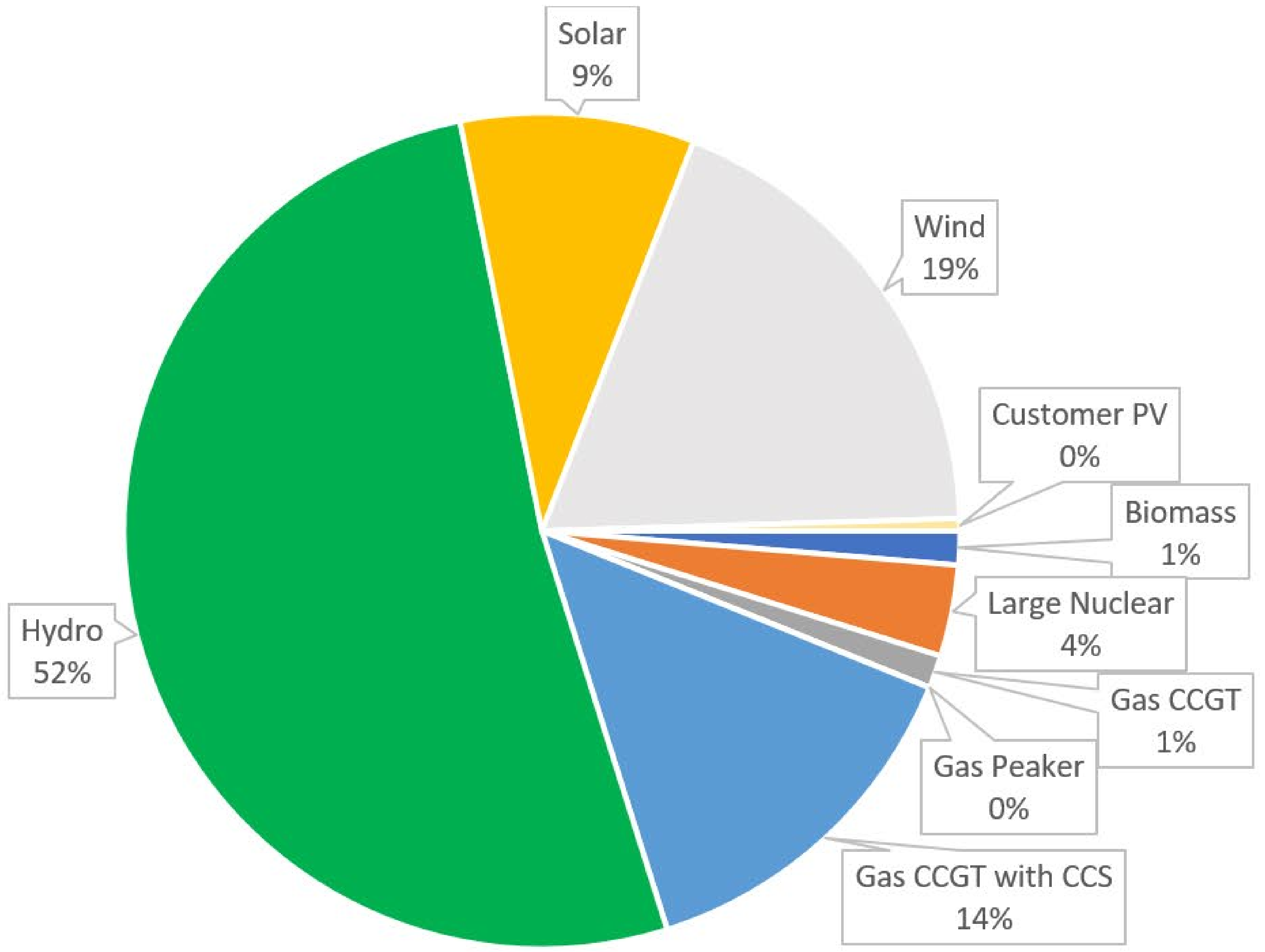
Total load (TWh) 257

Peak Capacity (GW) 45.7 -3.0

Resource Builds 2050



Energy Mix



ELECTRICITY SECTOR

Nuclear Scenarios

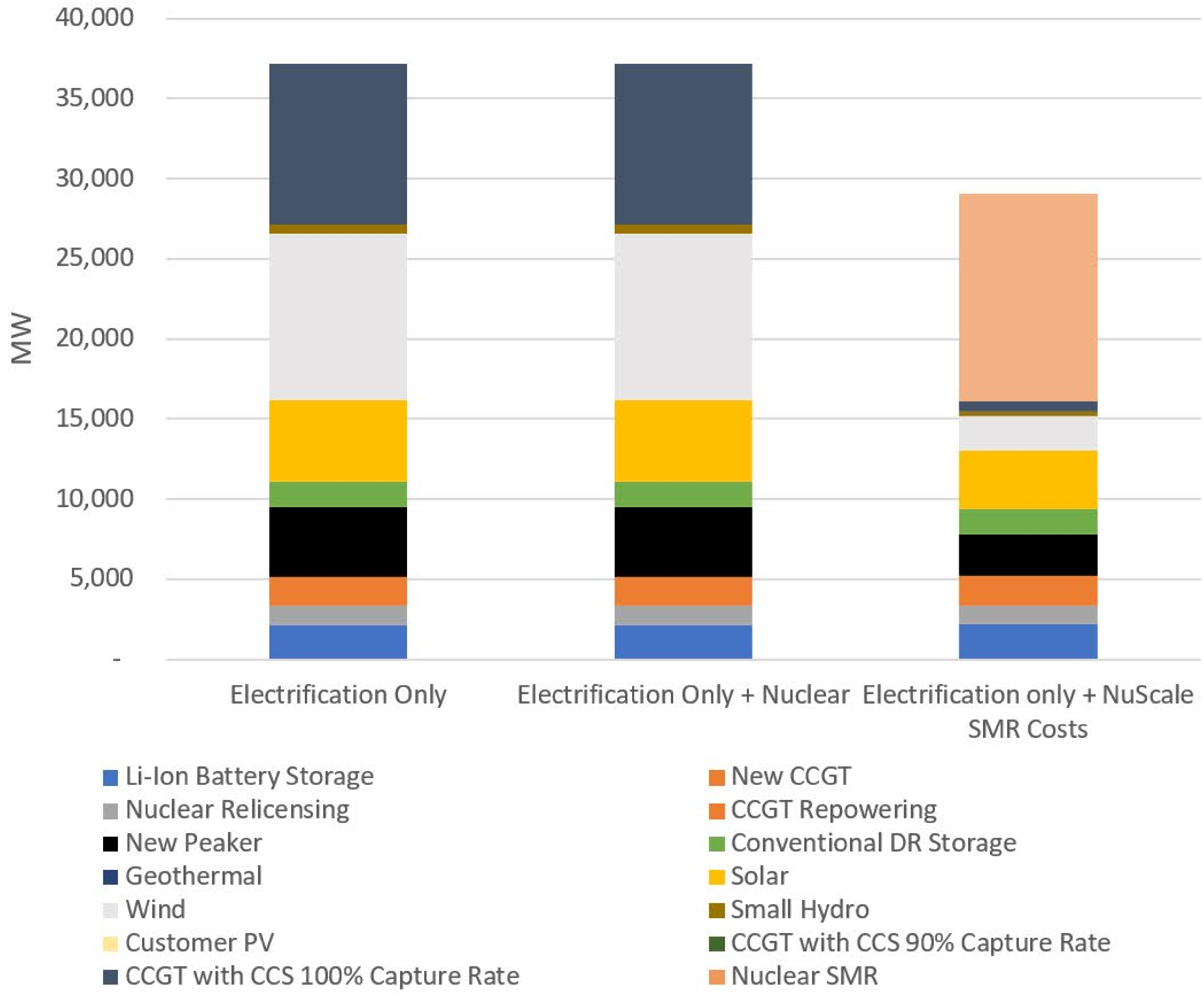
ELECTRICITY BY THE NUMBERS

System cost	$18.89 B	+ $7.4 B	+ $-1.57 B	= $25.32 B

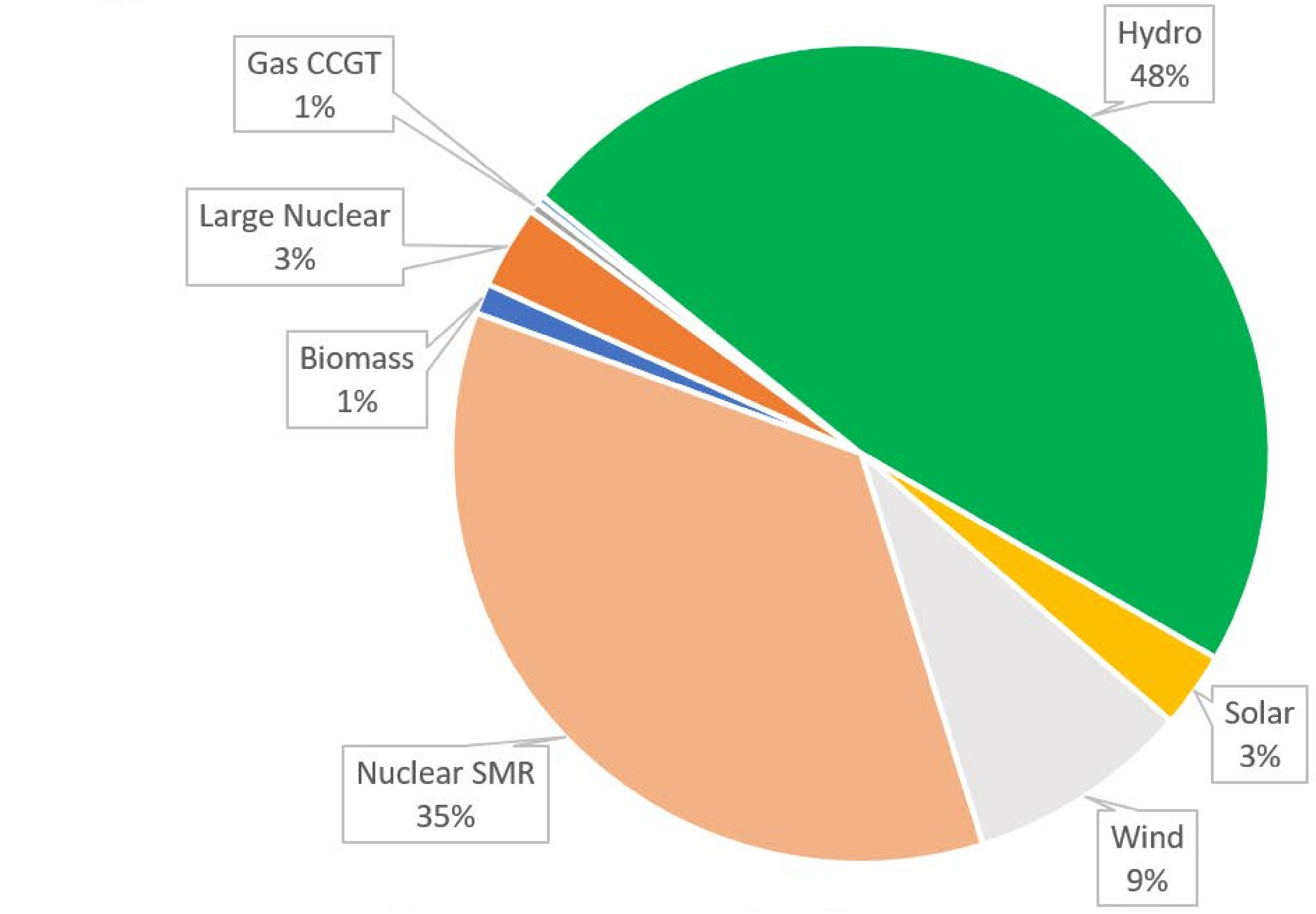
Total load (TWh) 257

Peak Capacity (GW) 45.7

Resource Builds 2050



Energy Mix

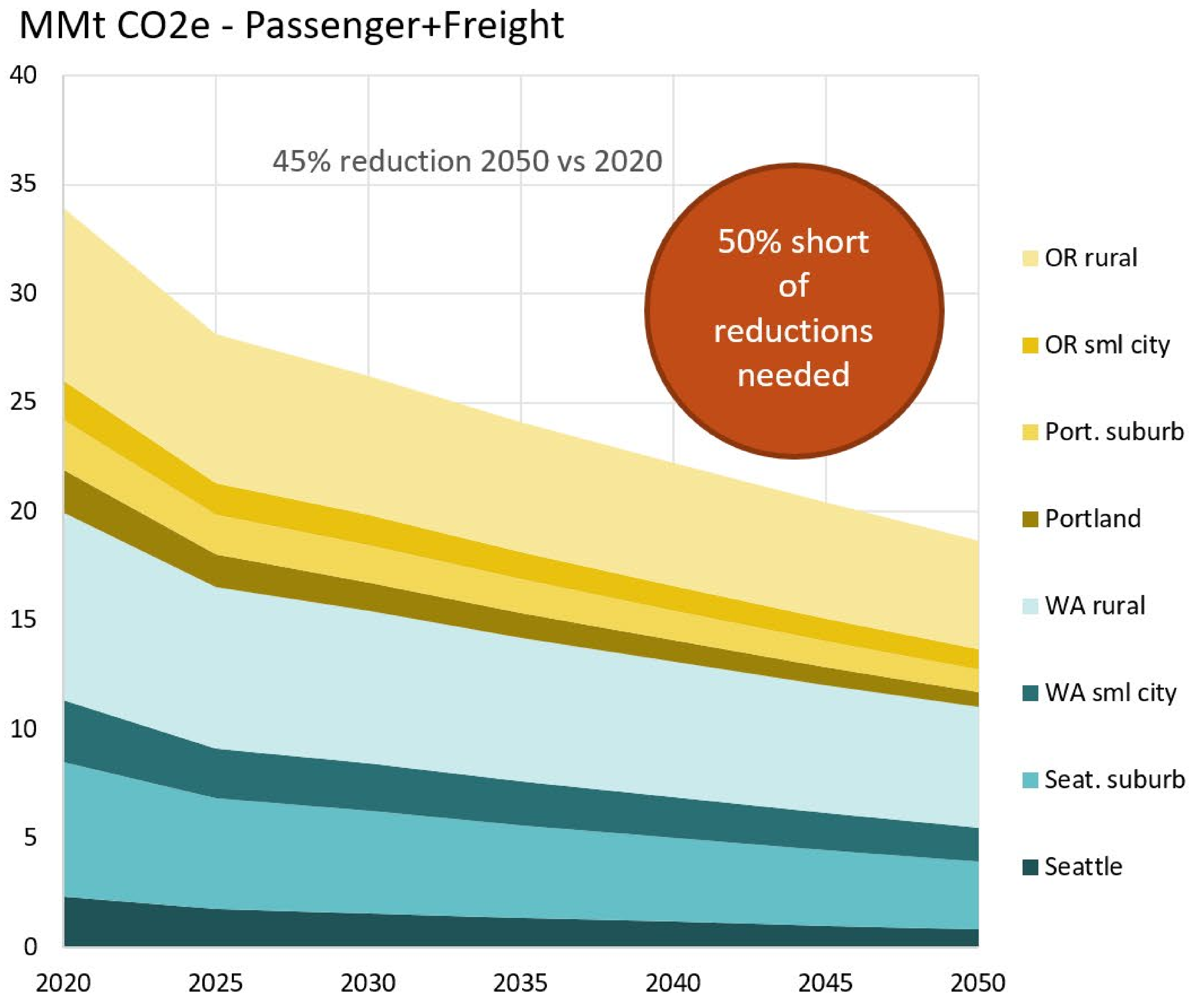


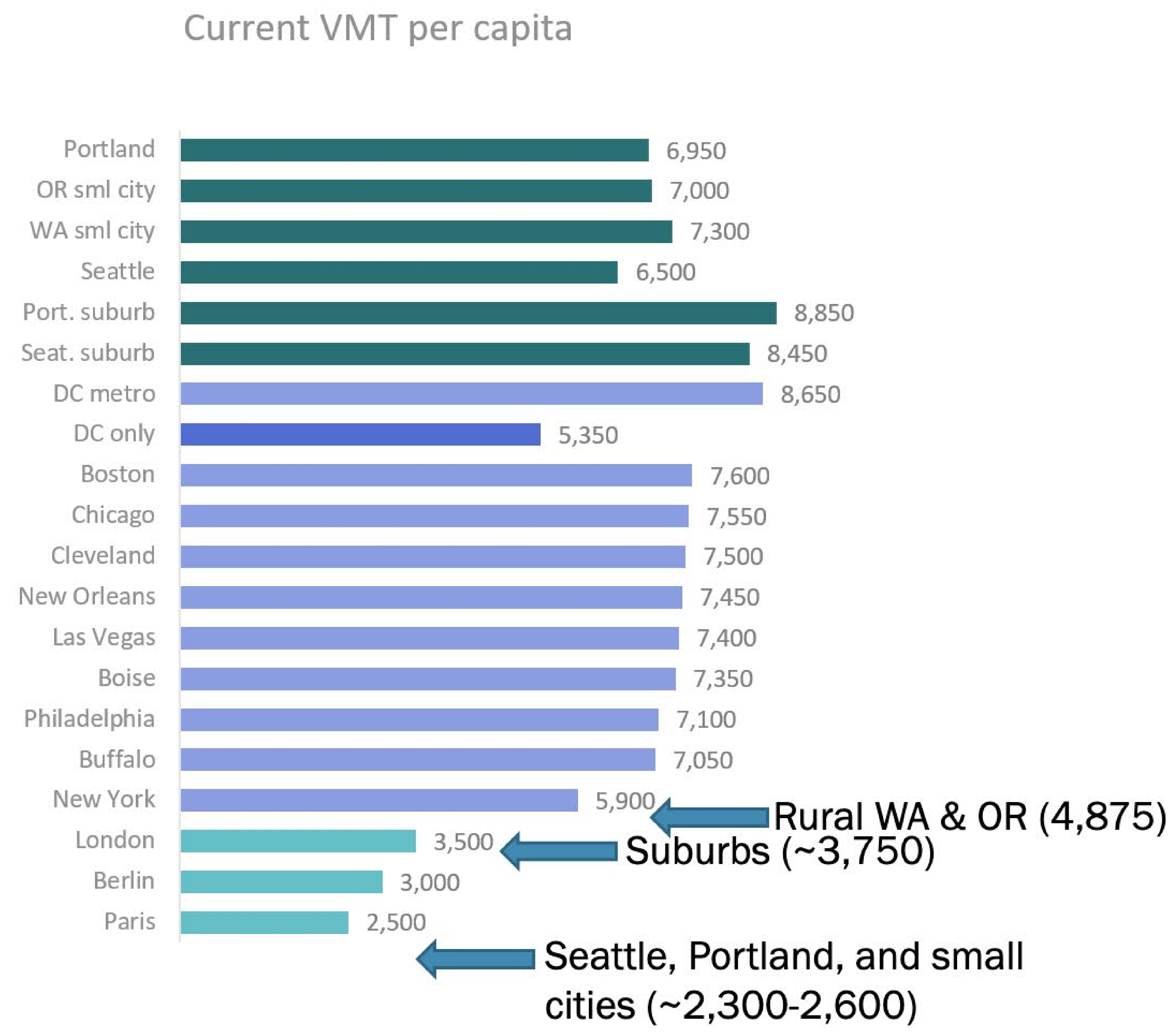
ADDITIONAL SCENARIOS:

What are the other possibilities?

ADDITIONAL SCENARIOS

55% VMT Reduction but no additional electrification beyond BAU





ADDITIONAL SCENARIOS

55% VMT Reduction but with electrification

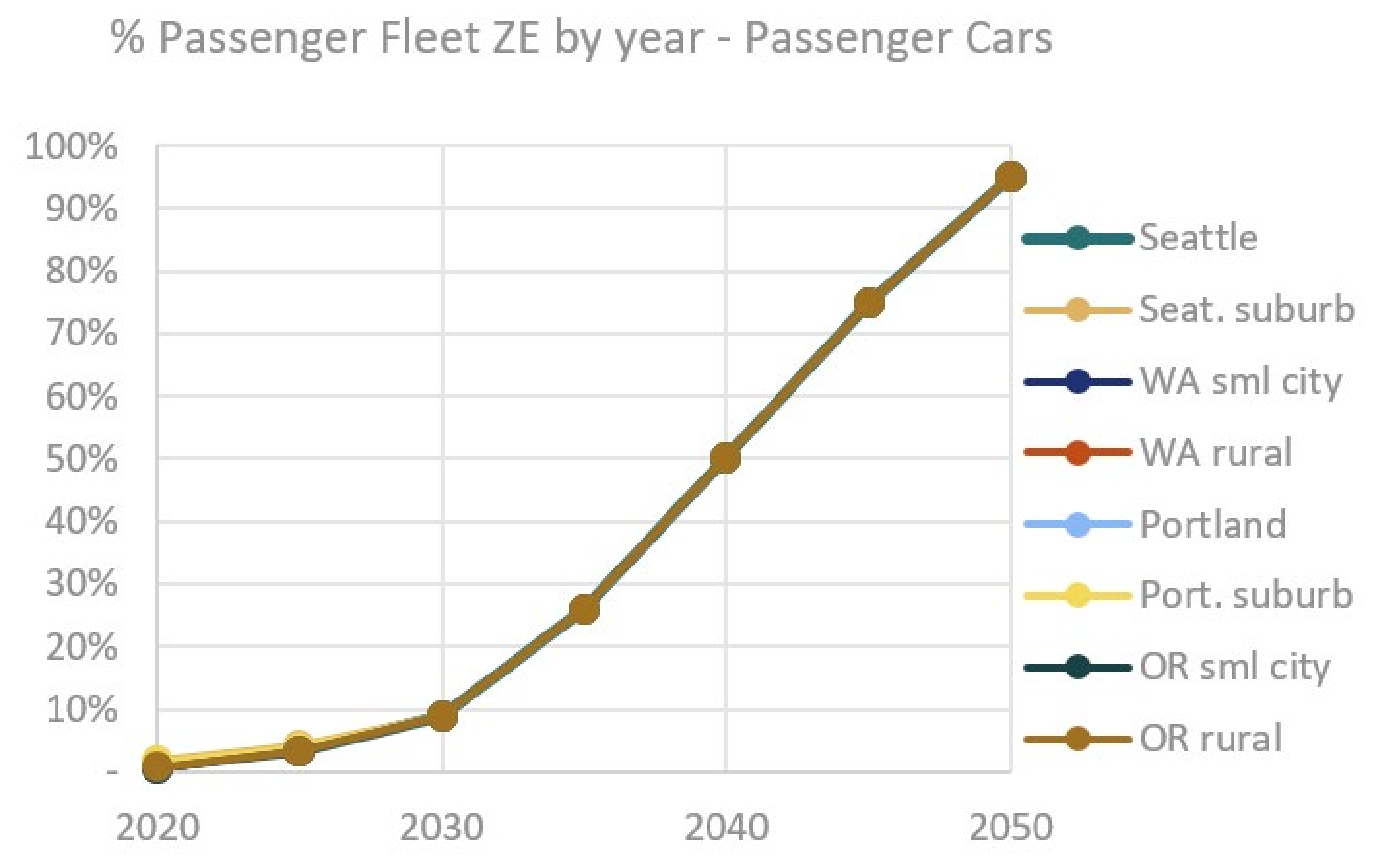
For the previous scenario to meet GHG goals we need:

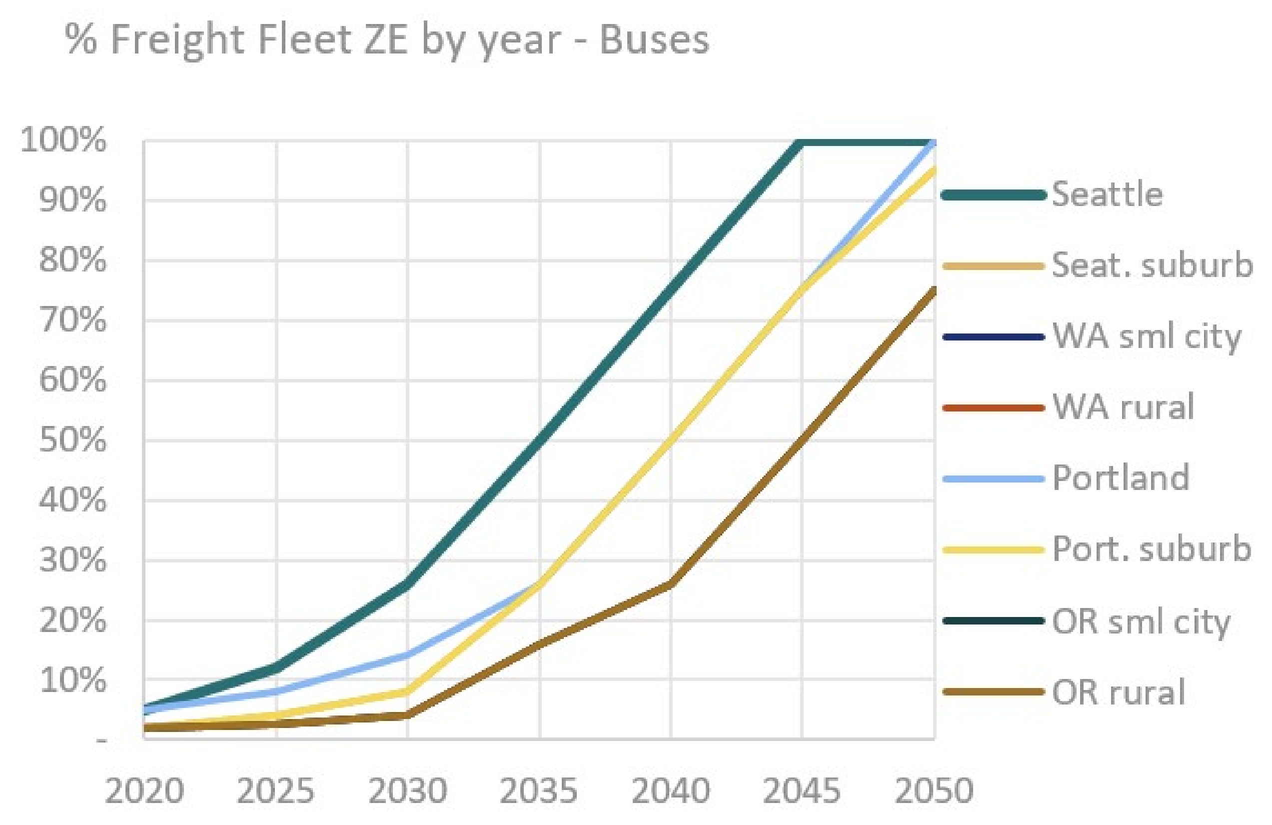
97% cars, light-duty

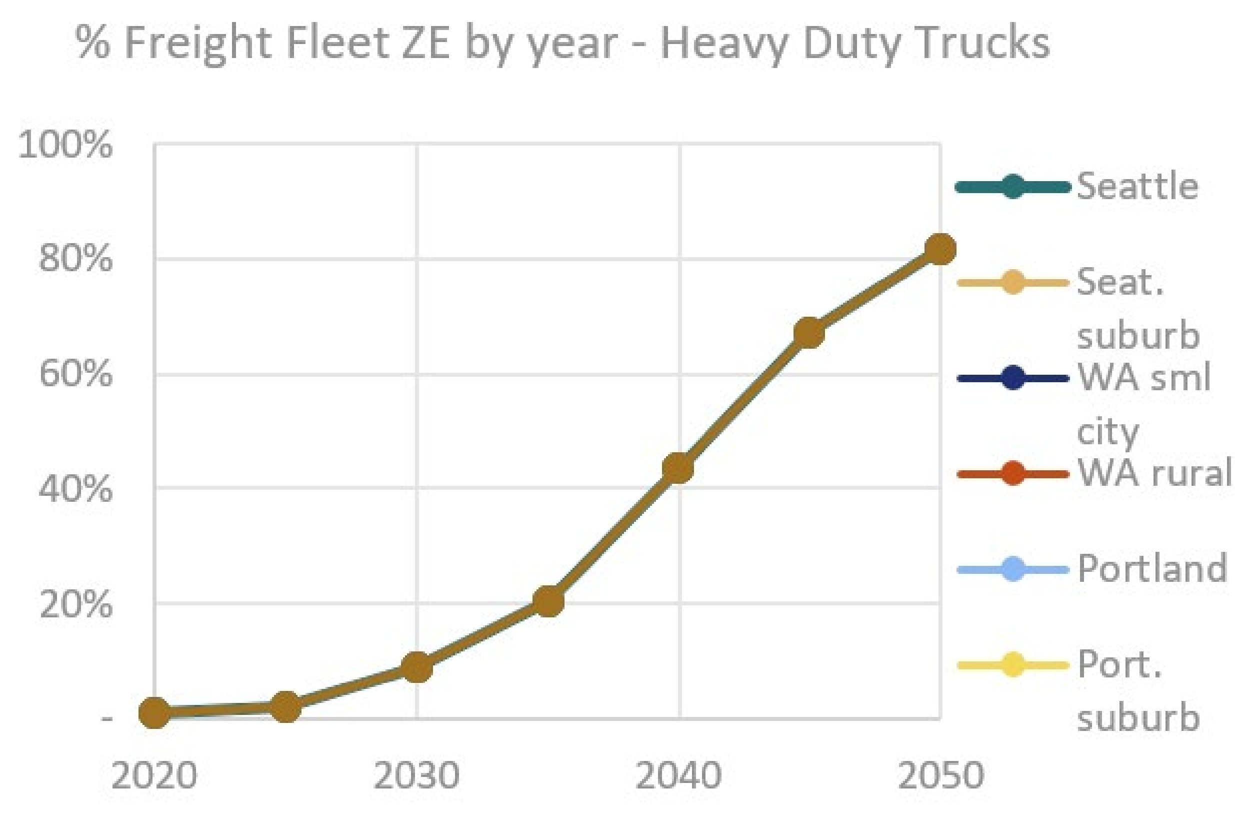
98% buses

96% medium- and heavy-duty freight

...to be electrified by 2050



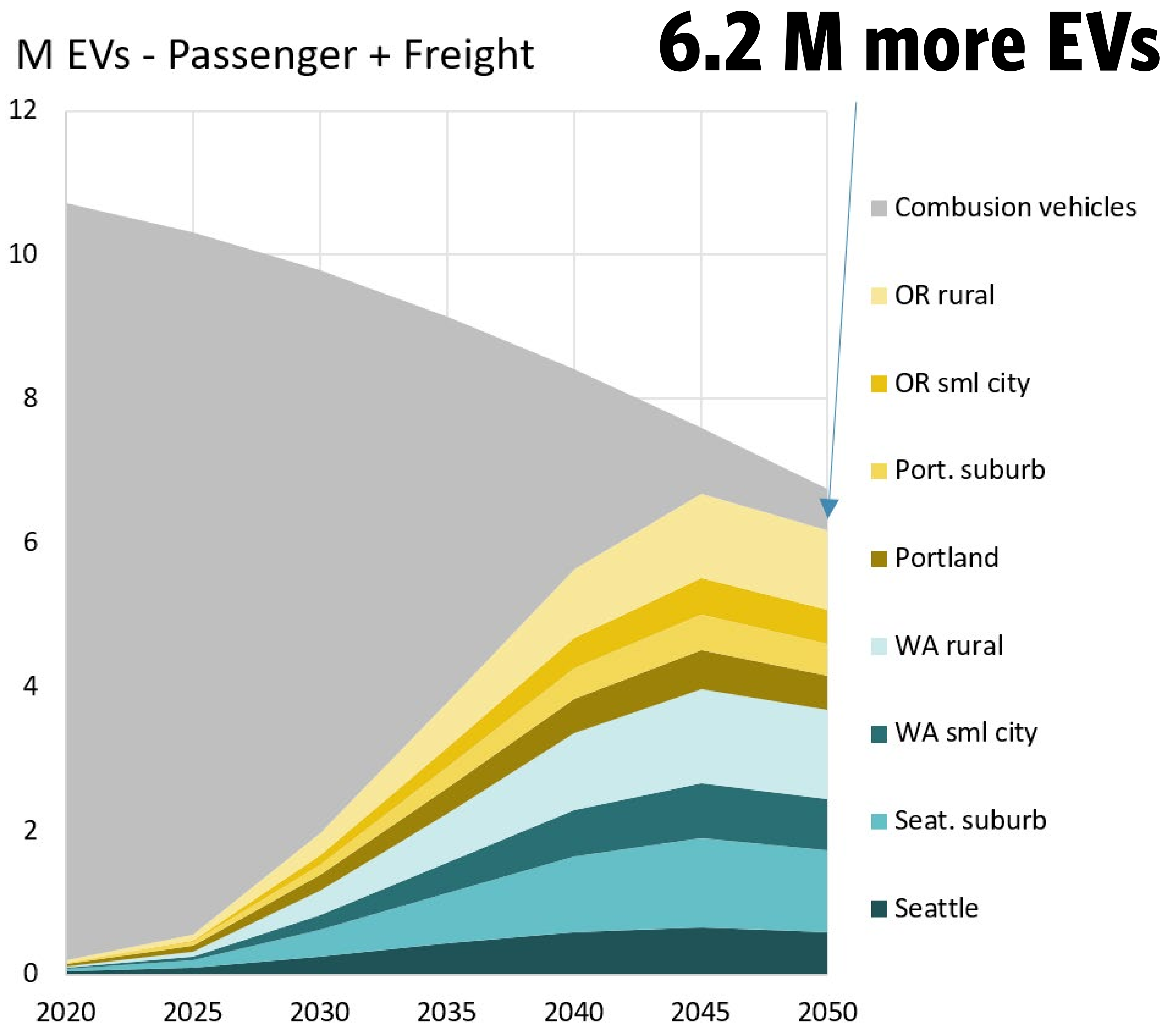




ADDITIONAL SCENARIOS

55% VMT Reduction but with electrification

Vehicles



Personal Spending

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

Public spending:

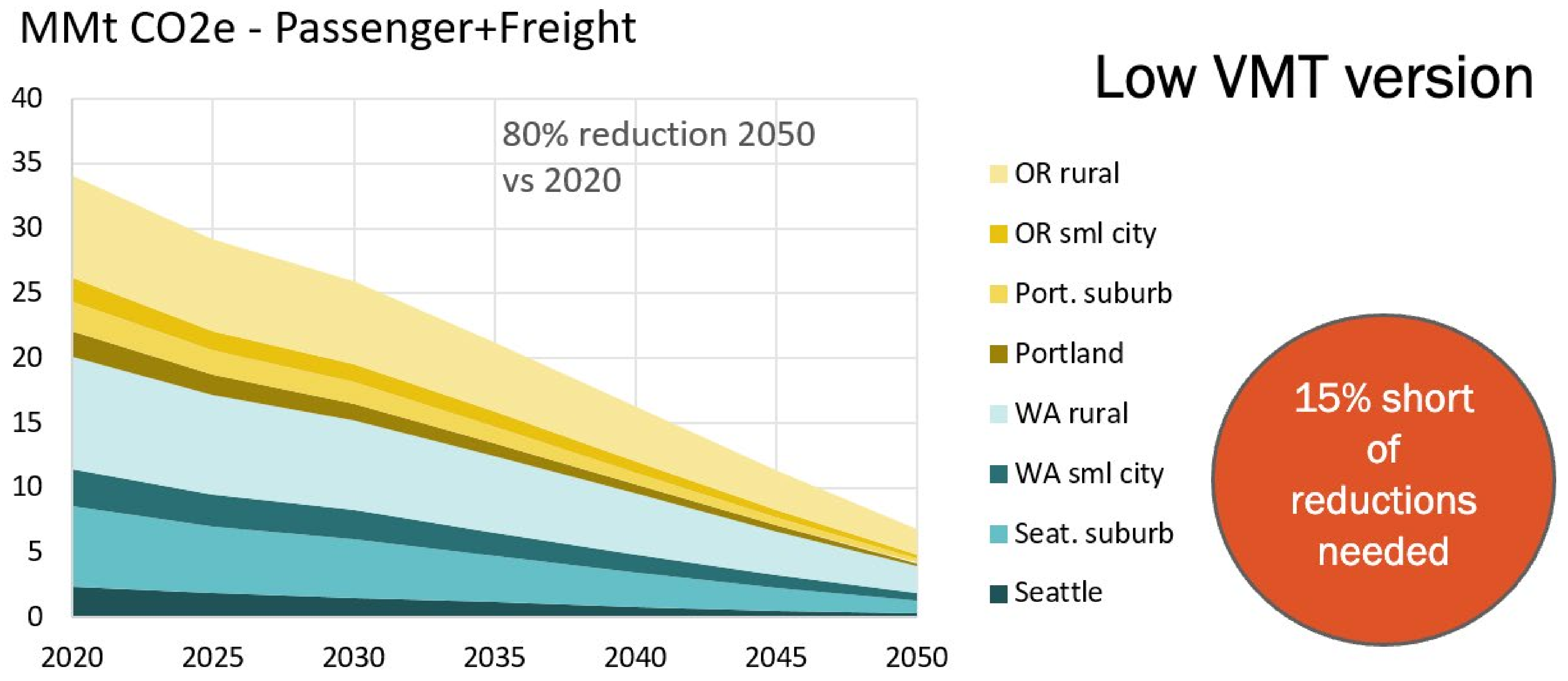
Roads: $5.1 B ($2.3 B less than Scenario 1)

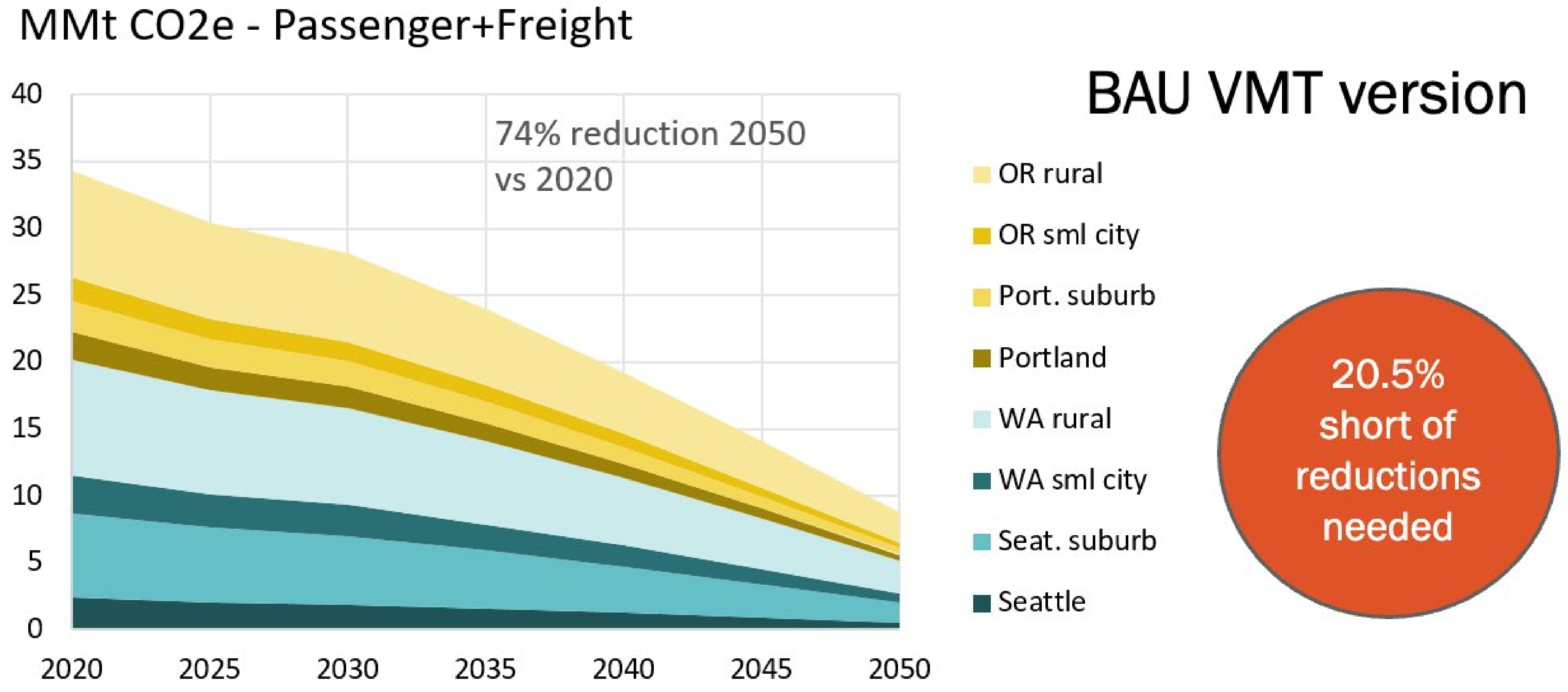
Transit: $8.3 B ($.7 B more than Scenario 1)

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?

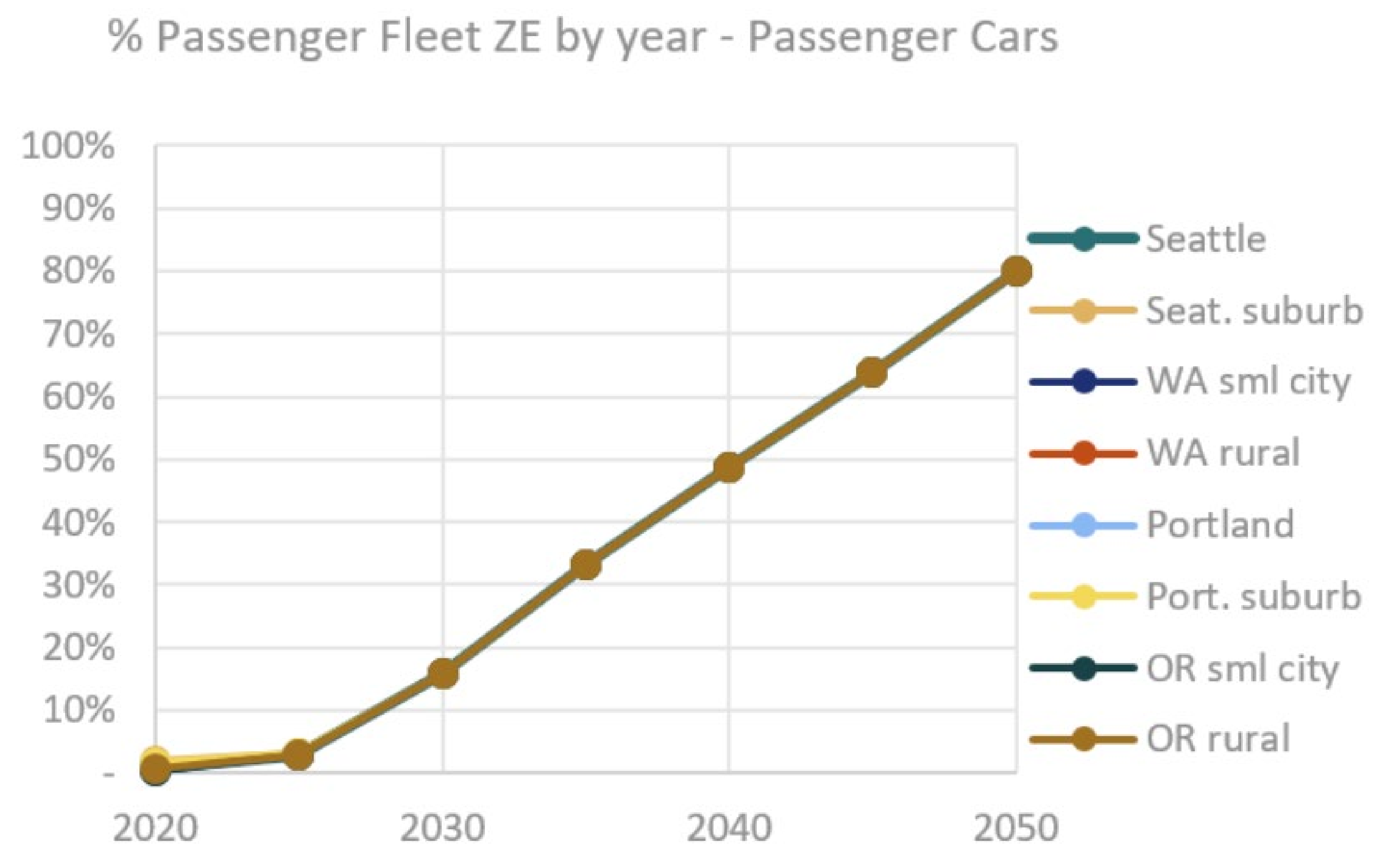
80% cars, light-duty

90% buses

75% medium-duty freight

72% heavy-duty freight

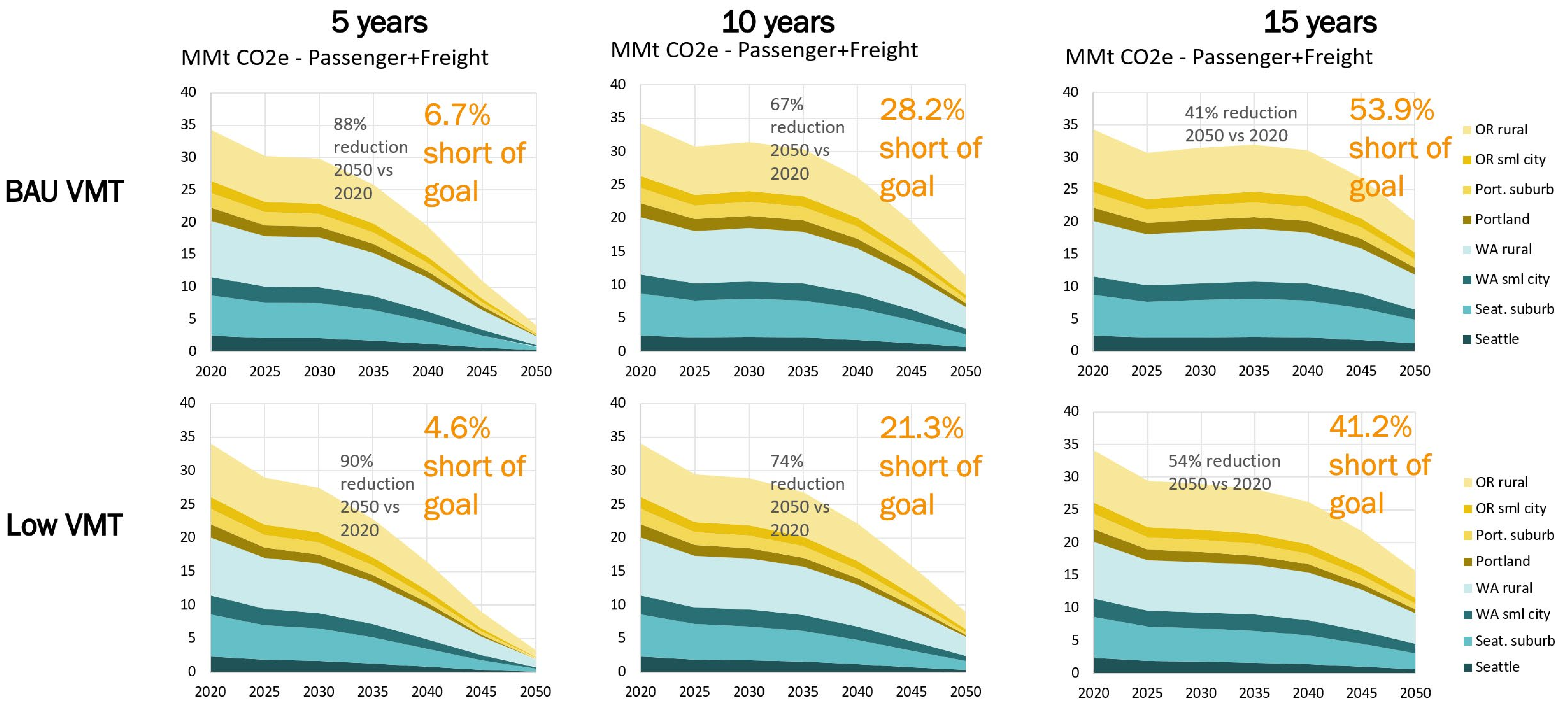
...are electrified by 2050



ADDITIONAL SCENARIOS

We cannot delay electrification uptake and still achieve climate goals.

Delayed Electrification



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

2050 shown unless otherwise specified	Automation + VMT increase vs. electrification-only
Cumulative CO_2 emissions 2020-2050	15 Mt more
Social cost of carbon, 2020-2050	$2 B more
Electrical power need	9 TWh more
Chargers	155 k more
$ for chargers	$500 M more
Electric vehicles	3 M more
People using buses	230 k fewer
Annual public road (no transit) spending in 2050	$1.8 B more
Annual transit expenditures* in 2050	$300 M less

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?


245
City Center/PSU
8 TO OHSU & VA HOSP
SEE WHERE
YOU

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

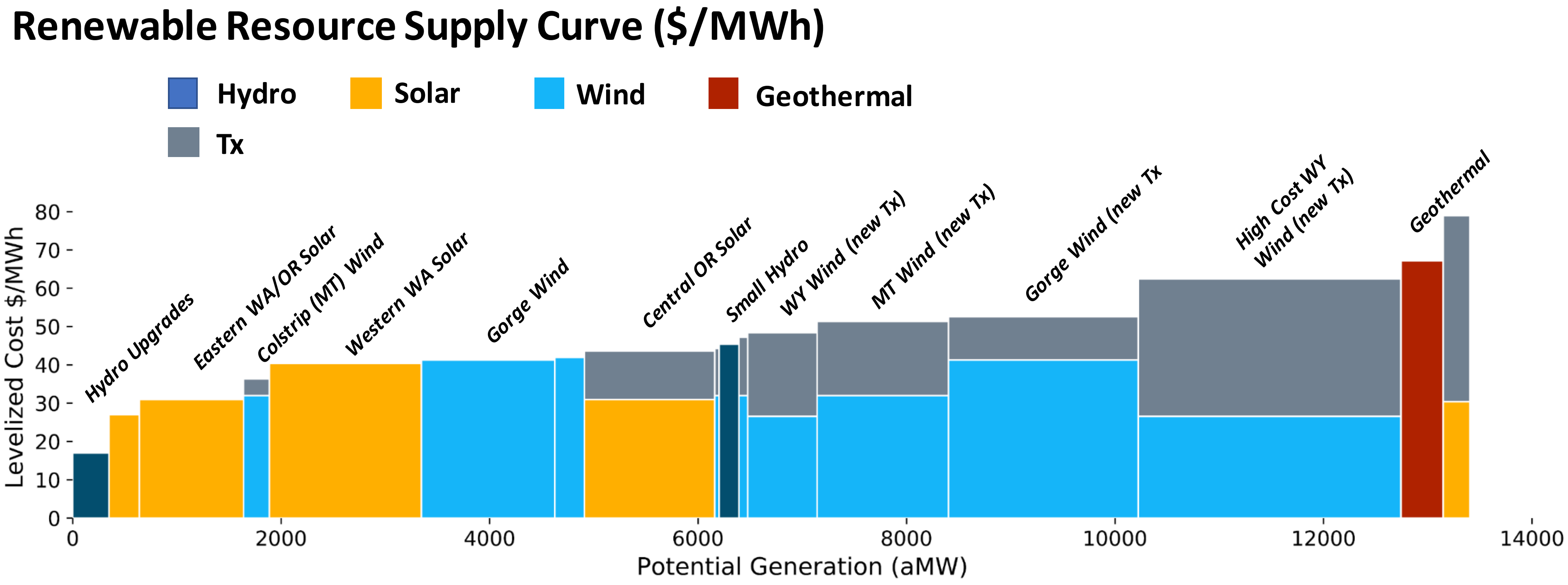
THIS IS 100% POSSIBLE.

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

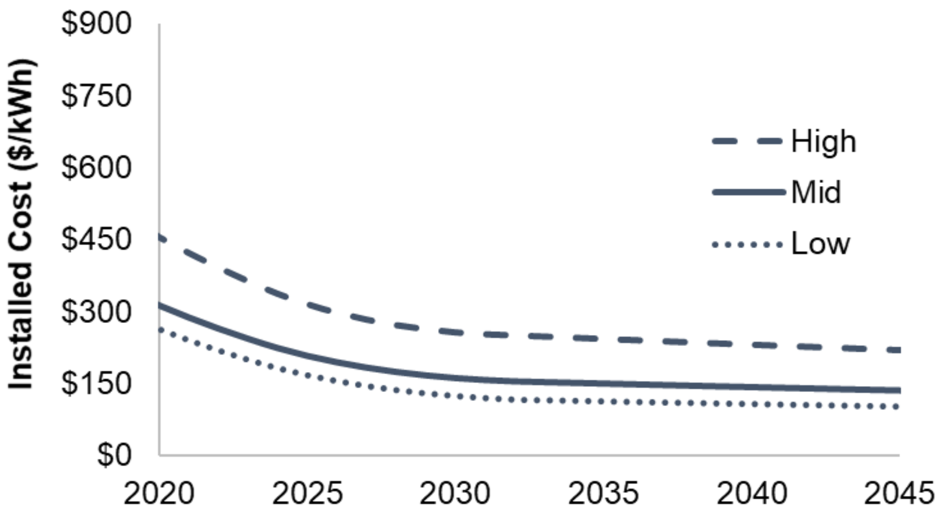
- Renewables available to the region are based on a supply curve that captures regional and technology diversity options for development
- Transmission adders reflect the need to ensure that new renewables built in the Northwest are deliverable to loads; scenarios with more renewables require more transmission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



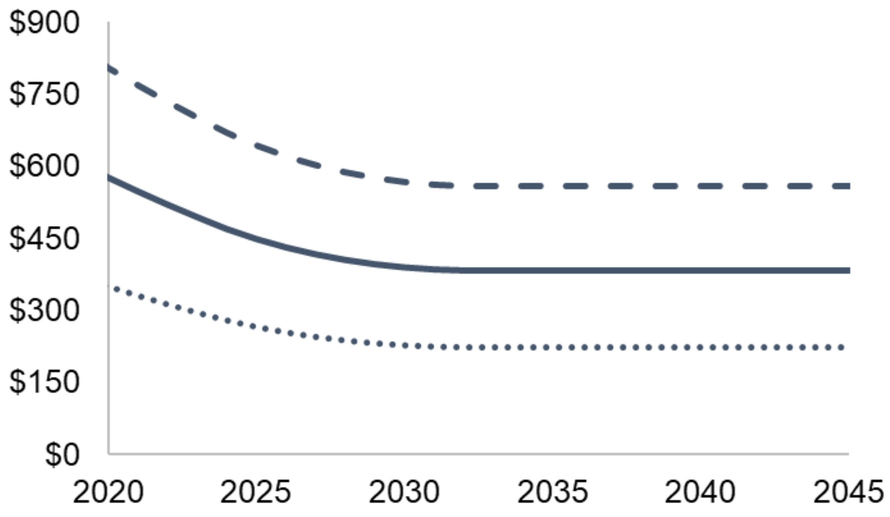
Energy Storage Costs

- **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)



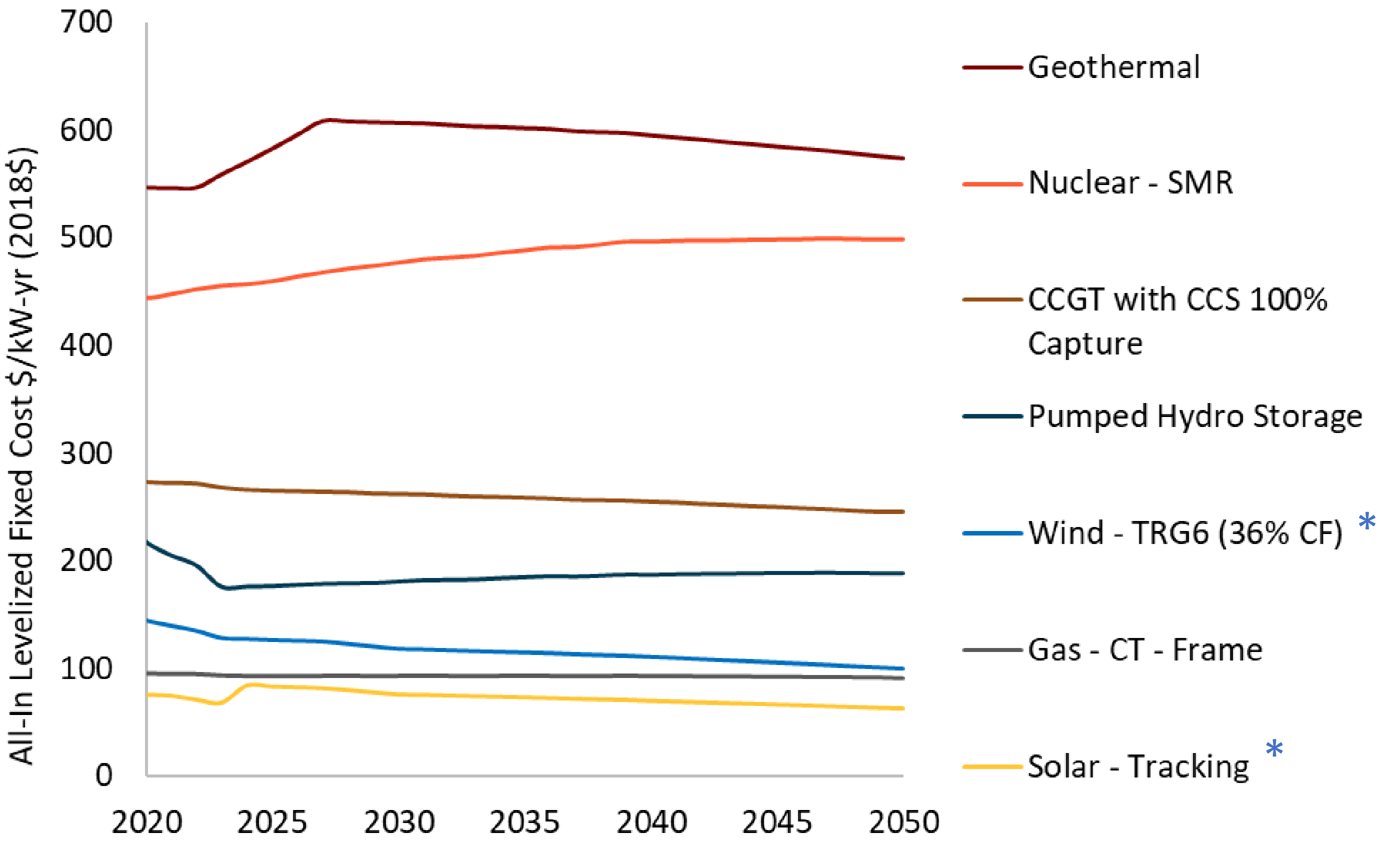
Flow Battery All-In Costs ($/kWh)



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**



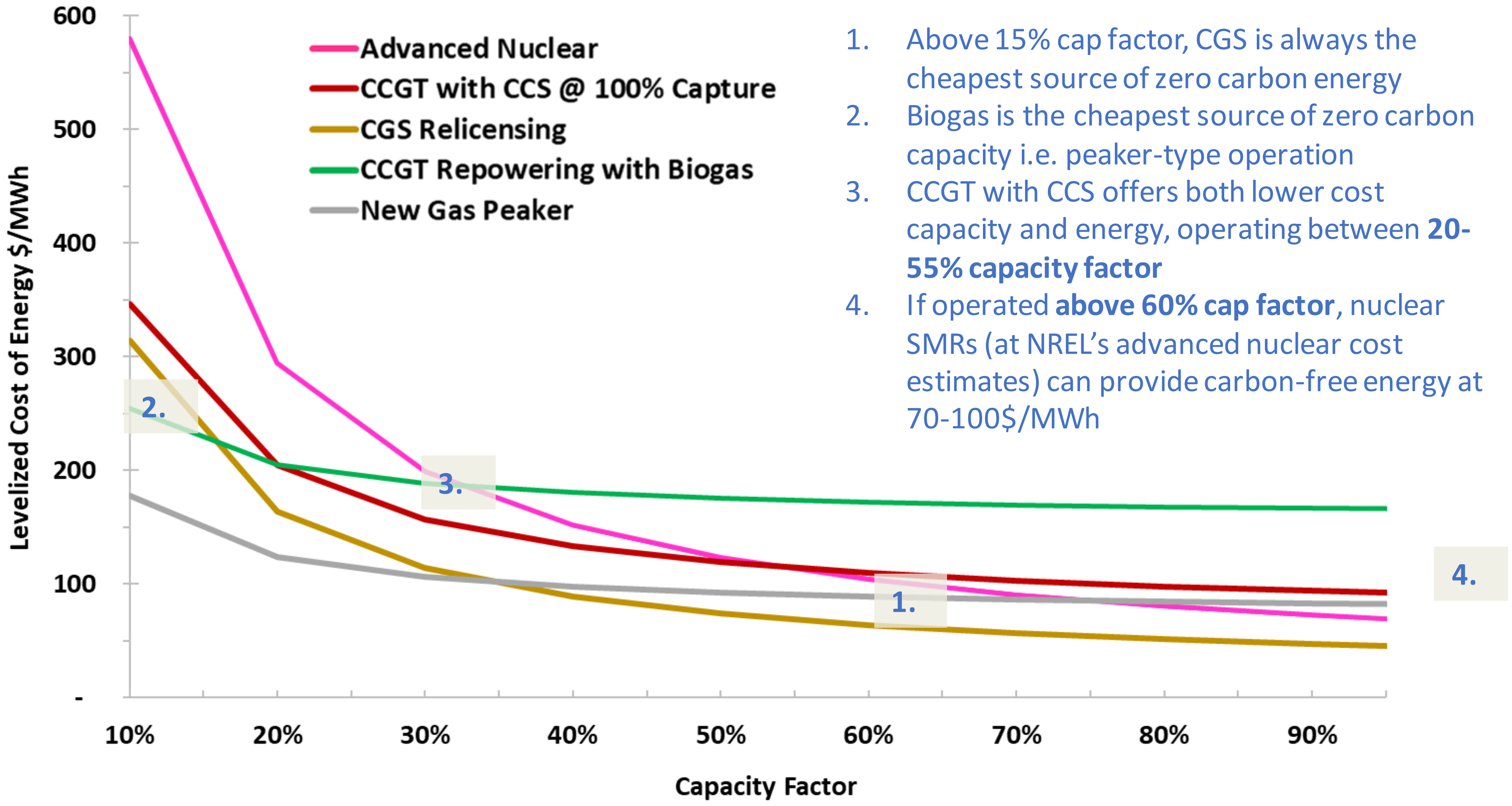
**Renewable resources are also subject to supply curve cost adjustments*

Key Resource Cost Parameters in 2045

Resource Type	2045 Capital Cost (2018 $/kW)	2045 Fixed O&M Cost (2018 $/kW-yr)	Operations
Utility-Scale Solar PV (Single-axis tracking)	$ 980	$ 12	No fuel cost
Onshore Wind (TRG6 - ~36% CF)	$ 1,080	$ 35	No fuel cost
CGS Relicensing	$ 406	$ 162	“Must run” with scheduled maintenance outages
NREL ATB Nuclear Small Modular Reactors (SMR)	$ 5,650	$ 99	Uranium fuel; Heat rate of 10,000 Btu/kWh; Flexible operations
Gas Combustion Turbine (Frame) – Peaker Resource	$ 850	$ 12	NG fuel; Heat rate 12,000 Btu/kWh
CCGT with Carbon Capture and Storage (Post-Combustion 90-100% Capture)	$ 1,700	$ 33	NG fuel; Heat rate 8,000 Btu/kWh; Operations equivalent to CCGT
4-hour Li-Ion Battery	$ 590	$2	Round trip efficiency of 92%
Biogas (a drop-in fuel to gas units)	N/A	Equivalent to Gas CT	High fuel cost ~23$/MMBTU

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

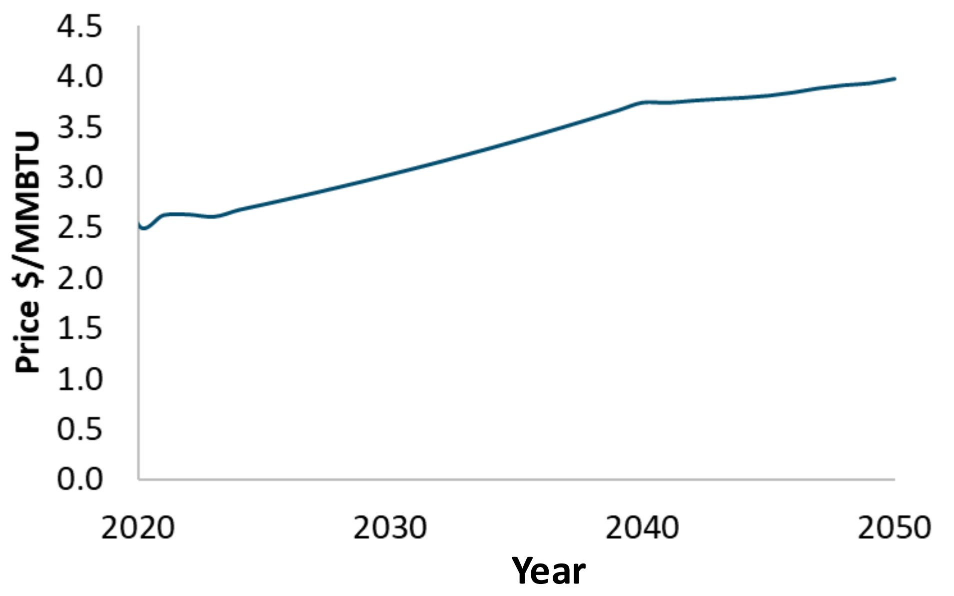


1. Above 15% cap factor, CGS is always the cheapest source of zero carbon energy
2. Biogas is the cheapest source of zero carbon capacity i.e. peaker-type operation
3. CCGT with CCS offers both lower cost capacity and energy, operating between **20-55% capacity factor**
4. If operated **above 60% cap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

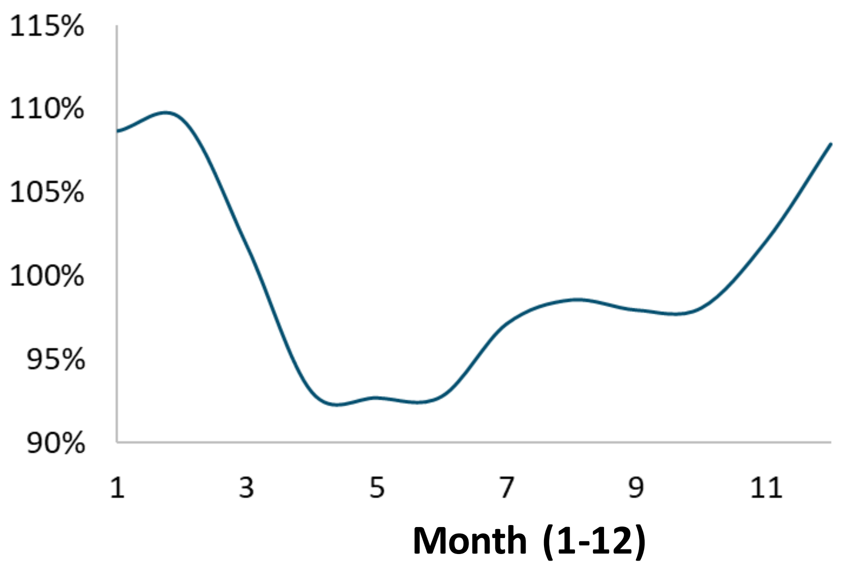
Natural Gas Core NW Price Forecast

- 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)

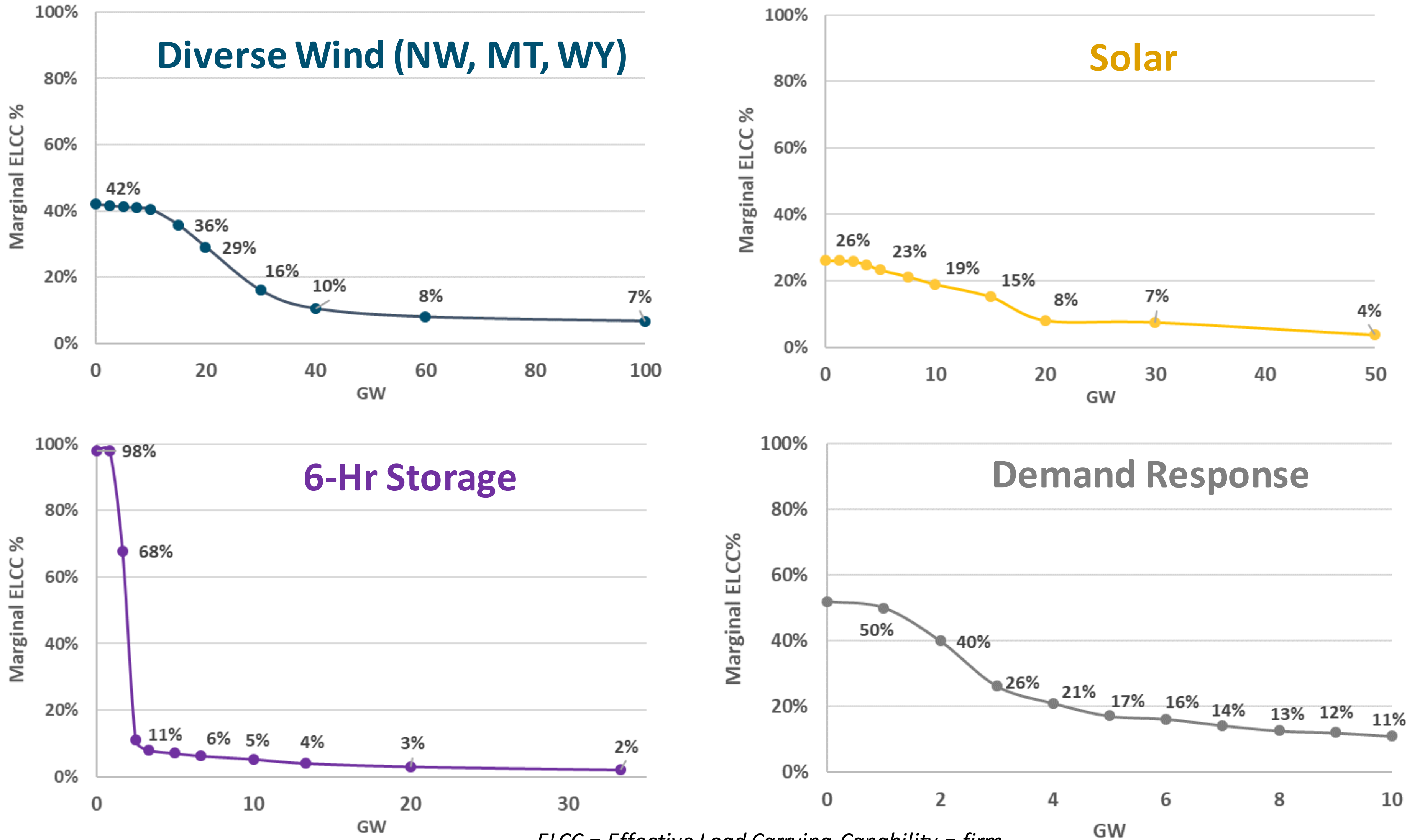
Core NW Natural Gas Price Projection– NW Dumas Gas Hub



Monthly Gas Price Variation (% relative to average)



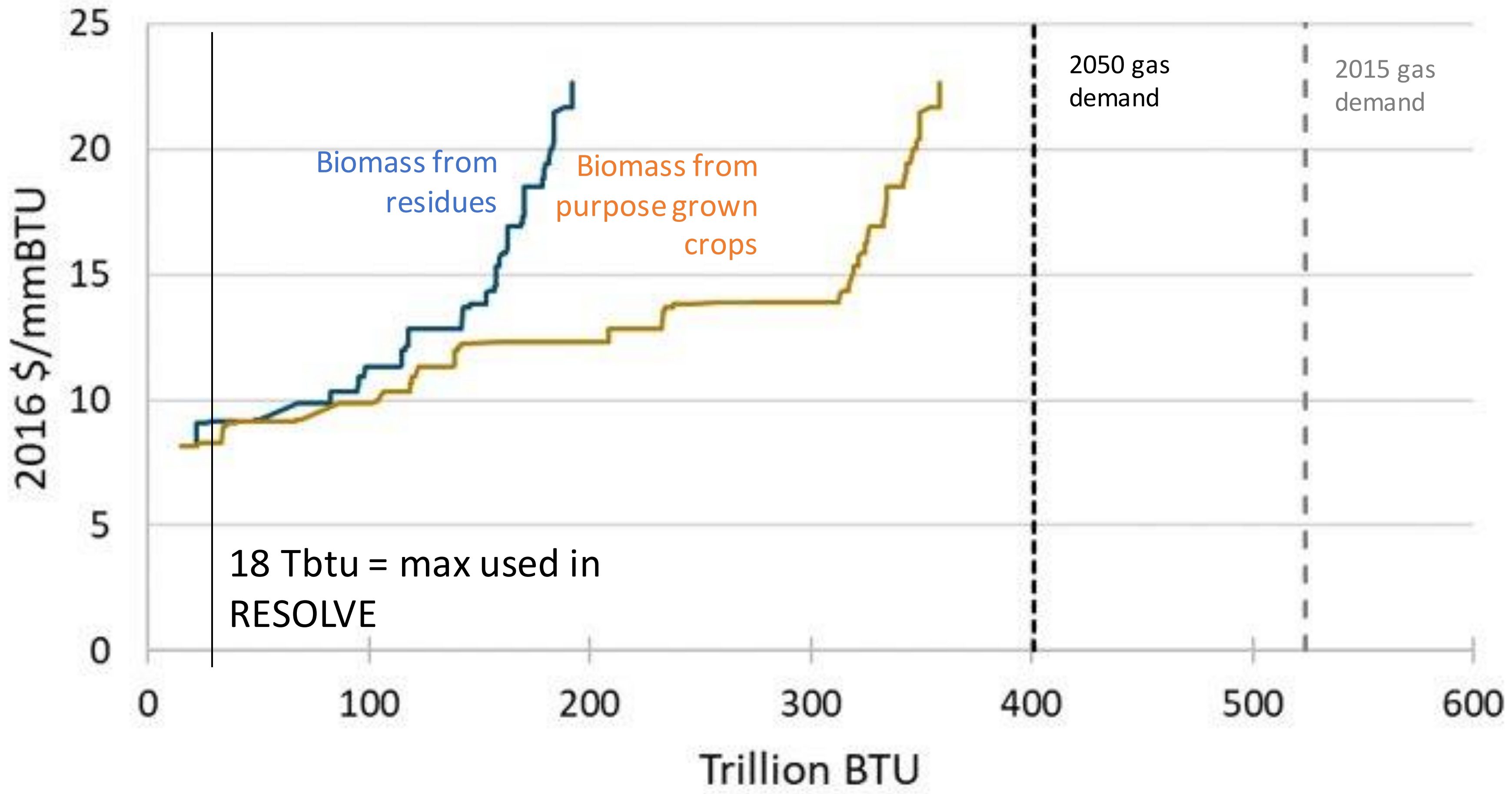
ELCCs sourced from *Resource Adequacy in the Northwest (2019)*



ELCC = Effective Load Carrying Capability = firm contribution to system peak load

Biomethane costs and quantities

Northwest Biomethane Supply Curve



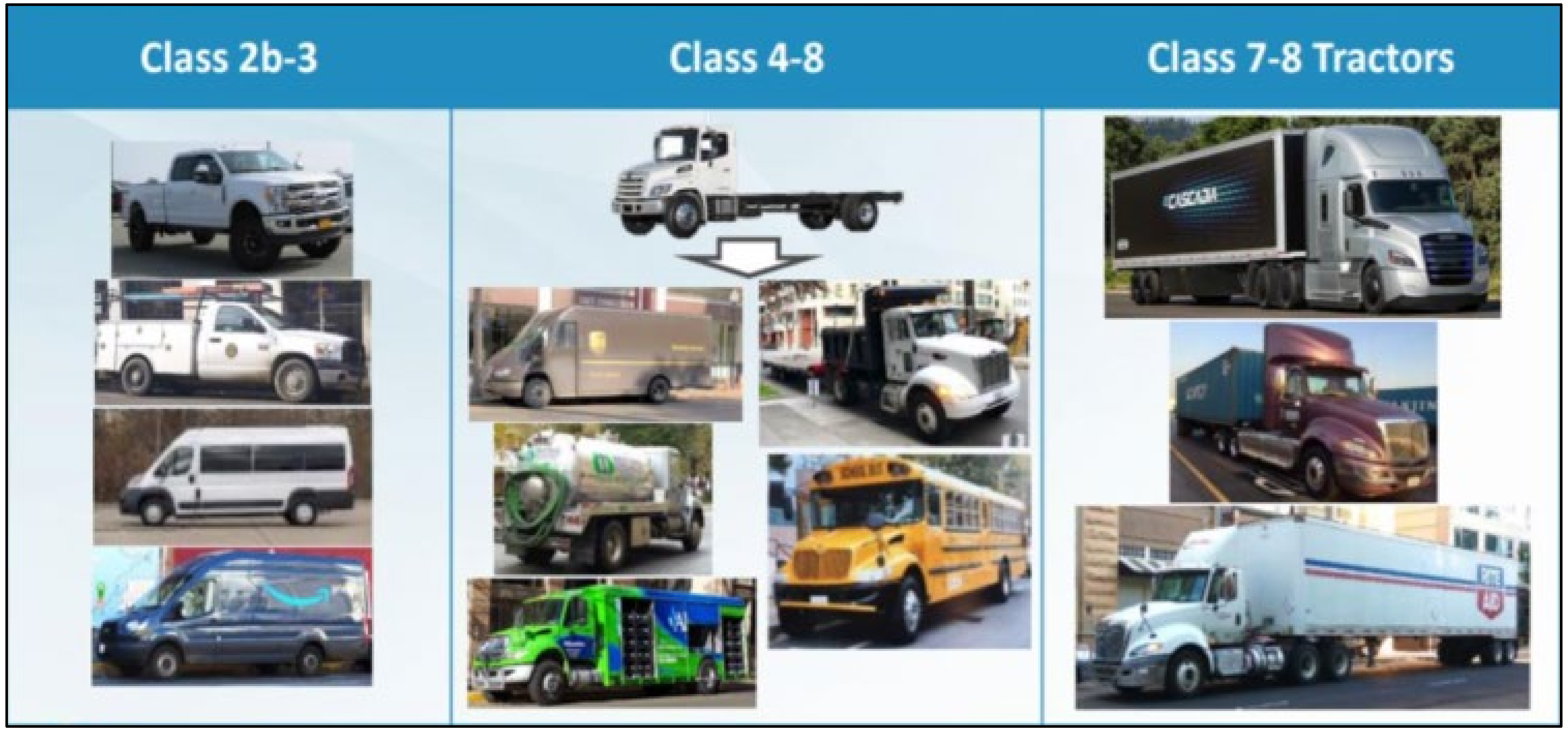
Notes: 1) supply curves sourced from *Pacific Northwest Pathways to 2050*
2) biomethane costs in RESOLVE reflect a market clearing price of $23/ MMBtu

CLEAN VEHICLES RULES

Newly adopted in the PNW

CLEAN VEHICLE RULES

The Clean Truck Rules are a set of two rules that require manufacturers to sell a percentage of electric and cleaner medium- and heavy- duty (MHD) trucks, as well as one rule that increases the number of zero-emission vehicles (ZEVs) sold (for passenger vehicles and light-duty trucks).



CLEAN VEHICLE RULES

Advanced Clean Truck rule

Will require manufacturers to produce and sell a minimum percent of new zero-emission medium- and heavy-duty trucks.

30-50% by 2030

40-75% by 2035

Passed OR November 18th

Passed WA November 30th

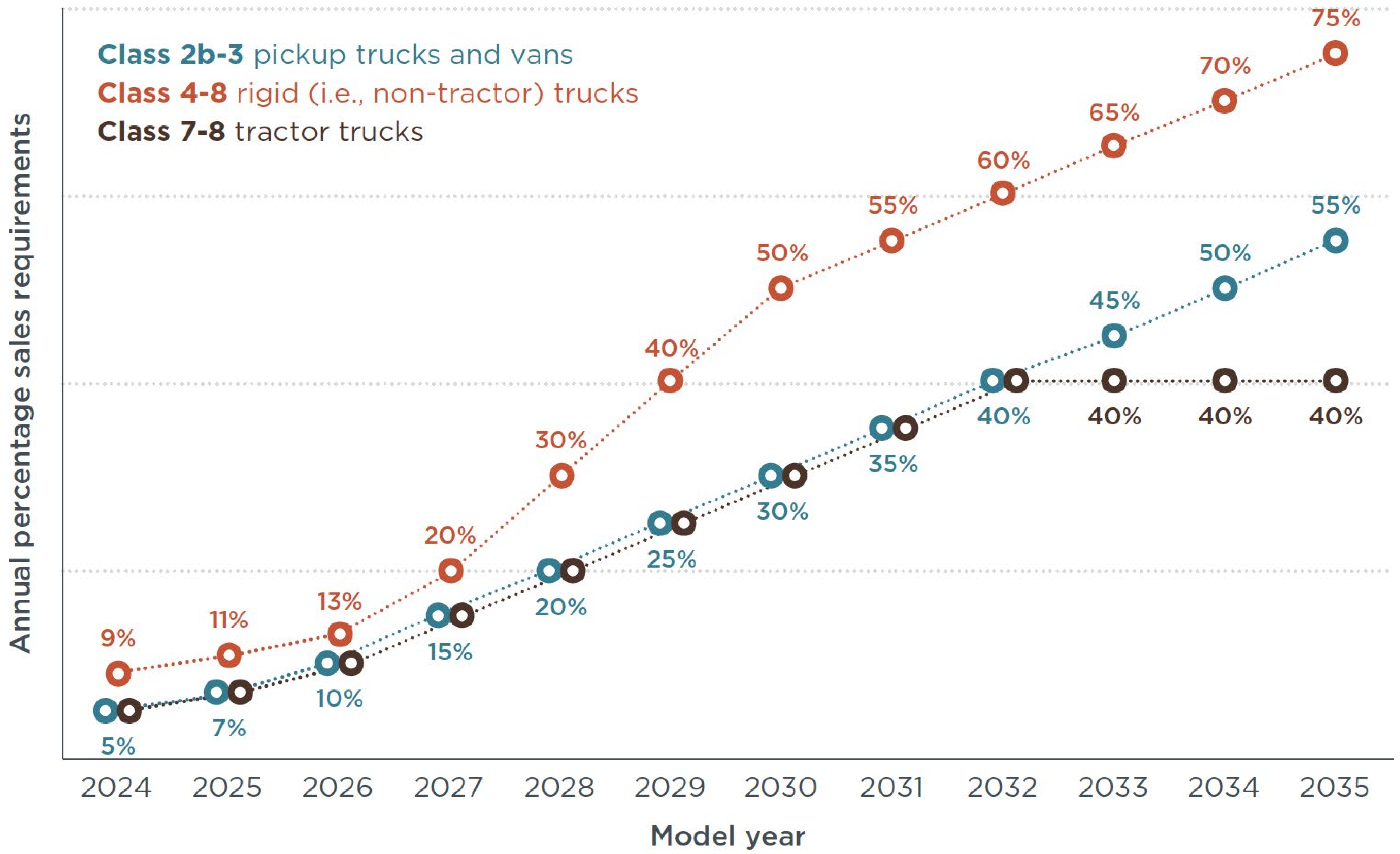


Figure 1: Zero-emission sales percentage schedule by vehicle group and model year.

CLEAN VEHICLE RULES

Low NO_X rule

An emissions standard that requires reduced nitrogen oxide emissions from new fossil fuel MHD trucks sold.

The new NOx standards would be cut to about 75% below current standards beginning in 2025 and 90% below current standards in 2027.

Passed OR November 18th

Expected in WA in 2022

CLEAN VEHICLE RULES

Why does this matter?

Transportation is the largest source of climate pollution in the PNW.

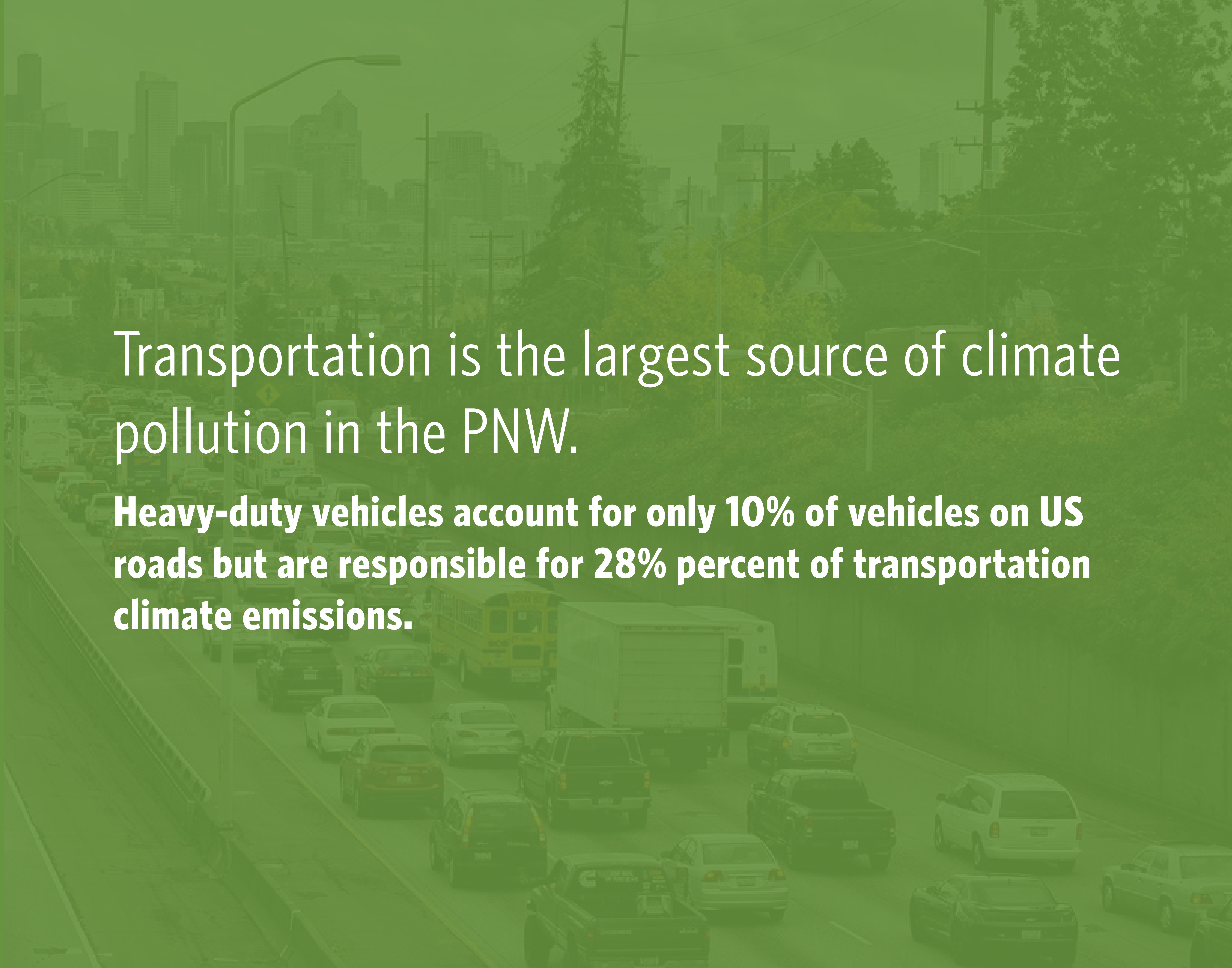
Heavy-duty vehicles account for only 10% of vehicles on US roads but contribute 28% percent of climate emissions from the on-road transportation sector.

Investing in zero-emission trucks is an investment in public health.

Air pollution from dirty diesel trucks disproportionately impacts low-income and BIPOC (Black, Indigenous and people of color) communities.

Every diesel truck, van, and bus we replace with a zero-smog, electric version creates immediate health benefits to local communities, families, workers, and truck drivers.

WHY DOES THIS MATTER?



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