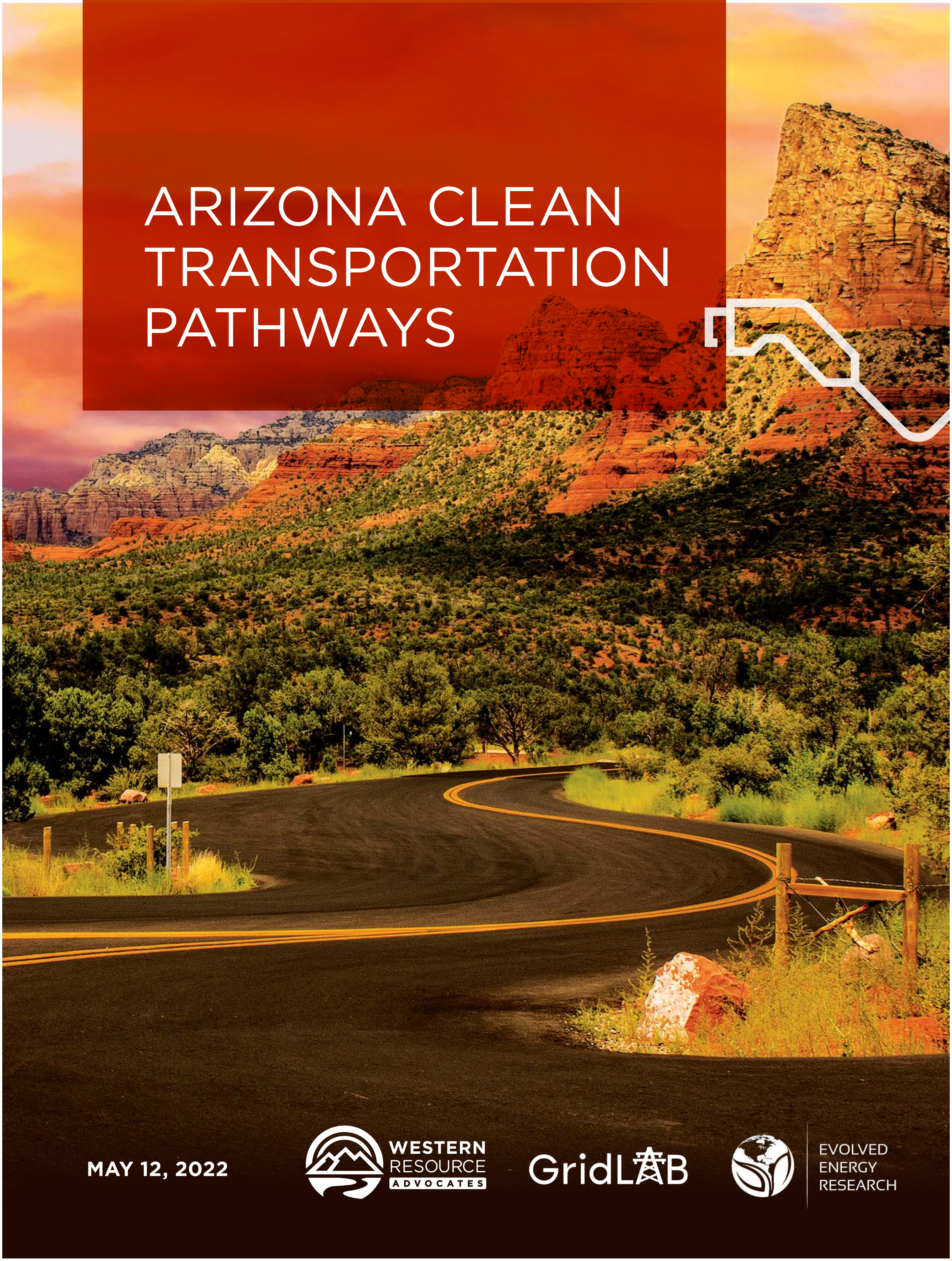
ARIZONA CLEAN TRANSPORTATION PATHWAYS



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WESTERN RESOURCE ADVOCATES
GridLAB
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INTRODUCTION

In the summer of 2021, Western Resource Advocates (WRA) commissioned GridLab and Evolved Energy Research for a joint study to investigate the role of transportation electrification in economy-wide decarbonization for the state of Arizona. As of early 2022, Arizona still lacks significant binding clean energy goals or transportation decarbonization measures. This study analyzes various pathways to decarbonizing Arizona's economy by 2050 and meeting emission reduction goals set out by the International Panel on Climate Change (IPCC),[1] with a particular focus on the relative costs of different decarbonization strategies in Arizona's transportation sector. The study also examines least-cost pathways to reduce carbon emissions from other sectors, including the power sector, in achieving economy-wide decarbonization. With the aim of developing pathways to help Arizona meet decarbonization targets that are aligned with internationally recognized climate goals, the project team designed and analyzed six transportation decarbonization scenarios centered around these key questions:

- What transportation goals should Arizona pursue in order to meet long-term decarbonization targets?
- How do energy rules within the power sector impact state investments?
- How fast do electric vehicle sales need to ramp up to achieve the lowest cost decarbonization outcome?
- What are the differences in possible infrastructure investments across sectors of the economy?
- What types of clean fuels, such as hydrogen or biofuels, will be required for Arizona to meet its transportation decarbonization goals?
- What are the relative costs of different transportation decarbonization strategies, and which is most favorable?

The technical report was completed on February 28, 2022. This report presents the main conclusions of the study.

1 In 2018, the IPCC published a report on the implications of limiting global average temperature rise to 1.5°C above pre-industrial levels, establishing 1.5°C as a common target threshold in many emissions reduction goals in the United States.

SUMMARY OF KEY RESULTS

- The **Clean Car and Truck** scenario represents the least-cost pathway for Arizona to achieve emission reductions in the transportation sector in order to meet internationally recognized climate goals.[2]
- In the **Clean Car and Truck** scenario, 100% of light-duty vehicle sales will be electric by 2035. In 2030, 1.4 million electric vehicles will be on the road, compared to just 180,000 in the **No Transportation Action** scenario. By 2035, when 100% of vehicle sales are electric, 3.2 million electric light-duty vehicles will be on the road.
- Transitioning to electric vehicles (EV) and fuel-cell vehicles (FCV) at the rate prescribed in the **Clean Car and Truck** scenario will significantly lower energy costs. Relative to this scenario, **No Transportation Action** will require Arizona to spend 1.9% of its gross domestic product (GDP) annually in 2050, amounting to **an additional $13.7 billion of spending**, on infrastructure related to electricity generation, fuel production, demand-side measures, and other energy components. Arizona's state GDP in 2020 was $373.7 billion.
- The cost of transitioning to a low-carbon electric sector while also electrifying transportation in Arizona has minimal impact on GDP. However, delaying action across any of these sectors would diminish opportunities for cost containment, resulting in greater economic repercussions by 2050. The **Delayed Action** scenario requires an additional 0.55% of GDP spending relative to the **Clean Car and Truck** scenario in 2040, or an additional $3 billion per year of energy spending in 2040.
- Rapid decarbonization of electricity is imperative. The retirement of coal by 2040 is key; study results show that retiring coal accounts for 66% of emissions reductions from the 2016-2018 emissions baseline.
- Electricity sector investments in 2050 will amount to over four times today's generating capacity while serving two times the load, including increased exports to the rest of the West. Additionally, generation will meet new electrolysis loads for fuels production.
- A dramatic expansion of the state's solar capacity is critical to meeting future power needs. Utilizing the best solar resource in the nation, Arizona will generate nearly 80 gigawatts (GW) of solar power by 2050 across most scenarios.

2 In the Clean Car and Truck Scenario, 100% of light-duty vehicle sales are electric by 2035, 100% of medium-duty vehicles are electric by 2040, and heavy-duty vehicle sales are 100% electric or hydrogen fuel-cell by 2040. This scenario is derived from the California Air Resources Board's nation-leading clean car standards, including the Advanced Clean Cars Program and the Advanced Clean Trucks rule.

STUDY DESIGN & METHODOLOGY

Evolved developed the decarbonization scenarios with the RIO model, a least cost capacity expansion optimization model with hourly operations that is constrained by scenario definitions, including emissions and electricity targets, the availability of resources, and their operational capabilities.[3] Unlike models that simulate whether a particular policy will reach the emissions goal, scenarios generated by RIO will always achieve the emissions goal if there are the resources to do so, but at varying levels of cost and investment, depending on the scenario being investigated. Comparing the differences between each scenario offers clarity about what type of transportation policy is most desirable in Arizona and the costs of not achieving that policy.

Six scenarios were developed, each looking at a specific set of assumptions and sensitivities about potential next steps that could be taken to transition away from internal combustion engines (ICE). The study starts with **No Transportation Action** — where no action is taken to move towards EVs/FCVs — followed by several other scenarios that vary in the rate and levels of transportation electrification/ fuel cell adoption, vehicle sales shares, and clean energy action. These range from simulating maximum feasible adoption rates to enforcing a clean electricity standard and are represented as Scenarios 2, 3, 5, and 6 in Table 2, which we refer to as **Core Decarbonization Scenarios**. Scenario 4, the **Delayed Action** scenario, represents a pathway in which the rate of EV adoption slows dramatically.

Modeling these scenarios also provides valuable insight into the differences between investments made in transportation, electricity, and other sectors of the economy. Table 1 describes each scenario and the questions that it aims to address, while Table 2 elaborates on scenario assumptions across a range of different economic and policy parameters.

Evolved's modeling approach explores pathways for Arizona to achieve a net-zero economy by 2050, with various interim decarbonization or clean energy targets. The EnergyPATHWAYS model is used to develop demand-side cases, evaluating each sub-sector of the residential, commercial, industrial, and transportation sectors to forecast economy-wide demand for all forms of energy. The RIO model then determines how to supply the energy required to meet that demand at least cost. The demand-side modeling is influenced by various efficiency or sales targets, while the supply-side modeling is constrained by transmission, clean energy resources, resource availability, and decarbonization targets.

3 More detail on Evolved Energy Research, RIO, and PATHWAYS can be found here: https://www.evolved.energy/about.

TABLE 1.

Scenario Summaries and Key Questions

SCENARIO	SUMMARY	KEY QUESTION
NO TRANSPORTATION ACTION	Investigates the challenge of meeting net zero emissions by 2050 if no action were taken to transition the vehicle fleet to EVs/FCVs. Conservative bookend using AEO Reference Case vehicle stocks through 2050	What is the cost of taking no action to transition vehicle stocks to electric and fuel cell?
MAXIMUM FEASIBLE ADOPTION RATE	Investigates the opposite bookend to No Transportation Action: Maximum feasible adoption rates of EVs/FCVs, representing aggressive action taken to transition vehicle stocks	What investments are needed, and how much would it cost to meet net zero emissions with rapid electrification of the vehicle fleet? Note this determines only physical infrastructure costs and not the potential distributional impacts of policy to achieve rapid transition.
CLEAN CAR & TRUCK	Investigates vehicle transition policy in line with California Air Resources Board (CARB) vehicle sales targets	What is the cost of achieving net zero when adopting CARB policy?
DELAYED ACTION	Investigates the challenge of achieving net zero emissions by 2050 when EVs and FCVs are adopted more slowly than in the Clean Car and Truck scenario	How are decarbonization costs impacted by slower policy or unforeseen challenges that prevent faster adoption on EVs and FCVs?
2040 CES	Investigates the challenge of achieving net zero emissions by 2050 and 100% CES by 2040	What investments are needed, and how much would it cost to reach a more stringent 100% CES on retail sales by a 2040 target?
2040 CES + CLEAN GAS	Investigates the impact of restricting pipeline gas to coming from only clean sources in 2040 and beyond	How costly is it to achieve a 100% CES in 2040 and restrict pipeline gas to only clean alternatives?

TABLE 2.

Scenario Assumptions

SCENARIO ASSUMPTIONS	1. NO TRANSPORTATION ACTION	2. MAXIMUM FEASIBLE EV ADOPTION RATE	3. CLEAN CAR & TRUCK	4. DELAYED ACTION	5. 2040 CES	6. 2040 CES + CLEAN GAS
Clean Electricity Policy	100% clean electricity by 2070, 50% reduction in carbon emissions by 2032, 80% reduction in carbon emissions by 2050 below an emissions baseline averaging 2016-2018 emissions				100% clean by 2040 80% clean by 2030	Same as 1,2,3,4
Economy-Wide GHG Policy	40% below 2016-2018 baseline levels by 2030, 100% below 2016-2018 baseline levels by 2050					
Clean Resource Qualification	Constrained only by transmission limits (clean energy can be imported from out of state if cost effective)					
Buildings: Electrification	Fully electrified appliance sales by 2035					
Buildings: Energy Efficiency	Sales of high efficiency tech: 100% in 2035					
Transportation: Light-Duty Vehicles	AEO Reference Forecast	100% electric sales by 2030, 50% by 2025	100% electric sales by 2035	Slower transition, 15-year delay to full electric sales by 2050	Same as 3	Same as 3
Transportation: Medium-Duty Vehicles	AEO Reference Forecast	100% electric sales by 2035	100% electric sales by 2040	Slower transition, 10-year delay to full electric sales by 2050	Same as 3	Same as 3
Transportation: Heavy-Duty Vehicles	AEO Reference Forecast	HDV short-haul: 100% electric sales by 2035 HDV long-haul: 50% electric by 2035, 50% hydrogen sales by 2035	HDV short-haul: 100% electric sales by 2040 HDV long-haul: 50% electric, 50% hydrogen sales by 2040 Buses 100% electric sales by 2030	HDV short-haul: 100% electric sales by 2050 HDV long-haul: 50% electric, 50% hydrogen sales by 2050	Same as 3	Same as 3
Industry	Generic efficiency improvements over reference of 1% a year; fuel switching measures; 80% decrease in refining and mining to reflect reduced demand					
Resource Availability	NREL resource potential; 6 GW of additional transmission potential per path; 2x REEDS Tx Costs; SMRs not permitted.					
Fuels	AEO Reference fuel prices; no sequestration potential (NETL Injection Potential Study); clean fuels have zero emissions associated with them, so sequestration credit is left in state of origin					Same as 5, but clean gas required by 2040

TRANSPORTATION

The transportation sector represents the largest component of the economy in terms of energy use, making up approximately 50% of final energy demand in 2021. As electric vehicle adoption increases in the various decarbonization pathways, electricity growth to power electric vehicles displaces primary fuel use. Any action taken in the transportation sector will thus have significant impacts on Arizona's economy-wide energy demands. In the **Clean Car and Truck** case, the electricity sector grows by 110%, compared to just 55% in the **No Transportation Action** case, in order to meet increased electricity demand. However, total energy use in the economy actually decreases, due to the increased efficiency of electric battery vehicles and electric building appliances, which use less energy than typical internal combustion engine (ICE) vehicles or gas building appliances. The **Core Decarbonization Scenarios**, which include **Maximum Feasible Adoption**, **Clean Car and Truck**, **2040 CES**, and **2040 CES + Clean Gas**, have 25% less total energy demand in 2050 compared to the **No Transportation Action** case, which significantly reduces supply-side resources needed to meet load. In contrast, the **Delayed Action** scenario only reduces final energy demand by 21% relative to **No Transportation Action,** with significantly higher energy use in interim years, due to the slow adoption of highly efficient electric vehicles and electric appliances.

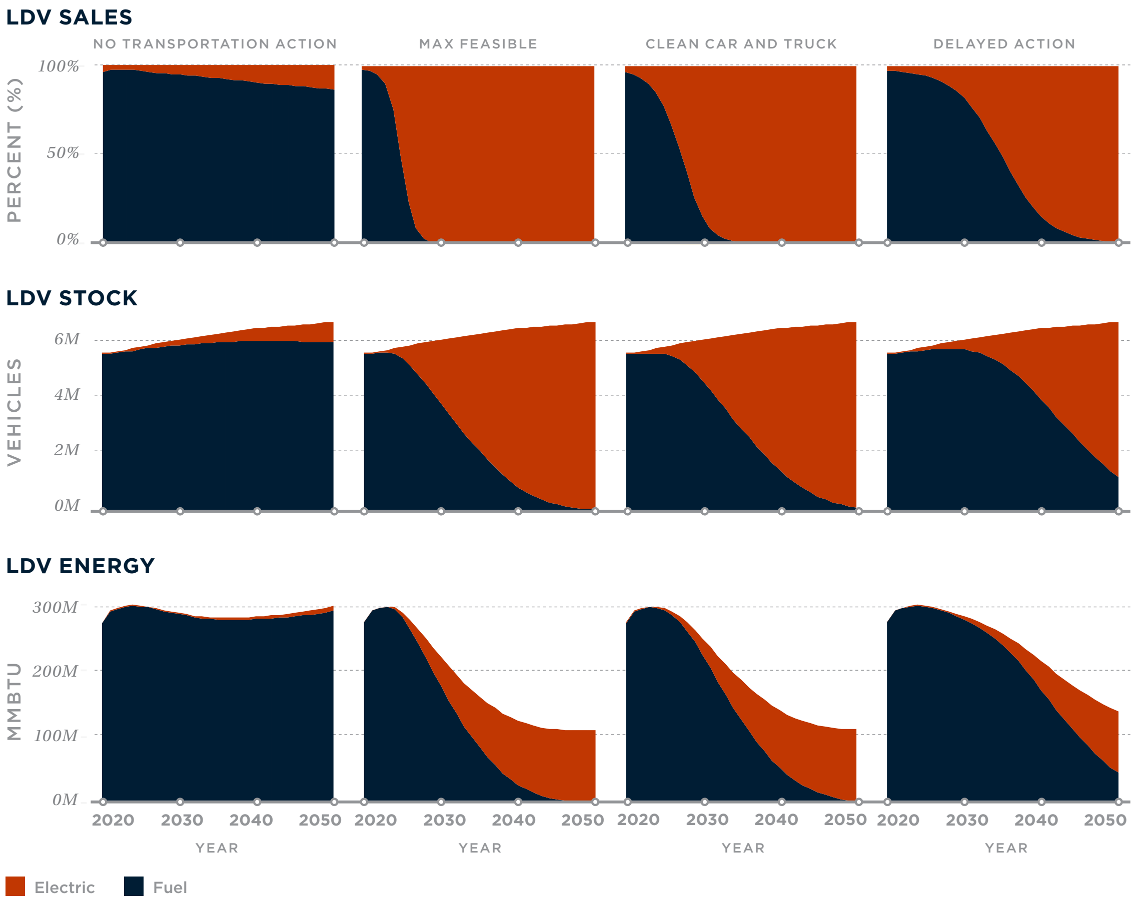
The reduction in total energy demand and increase in electricity generation is primarily due to rapid adoption of electric vehicles. The demand-side assumptions in other sectors, such as buildings and industry, remain constant across scenarios, while sales targets of electric vehicles vary throughout the scenarios. The sales assumptions of electric vehicles are based on stock turnover, in which vehicles are retired at the end of their useful life, as detailed in Table 2. In the **No Transportation Action** case, a conservative sales target of EVs based on the Annual Energy Outlook (AEO) Reference case[4] leaves the vast majority of the vehicle fleet

4 https://www.eia.gov/outlooks/archive/aeo21/

dependent on liquid fuels by 2050. In contrast, in the **Maximum Feasible Adoption** and **Clean Car and Truck** scenarios, EV sales accelerate to the point that nearly every vehicle on the road in 2050 is electric. Figure 1 presents an example of the stock turnover dynamic for light-duty vehicles across four scenarios.

FIGURE 1.

Light-duty Vehicle Sales, Stock, and Energy



The vehicle stock turnover is an important dynamic in considering the various pathways of transportation decarbonization. As detailed in Figure 2, the scale of electric vehicle deployment increases rapidly, far above the projections utilized in the **No Transportation Action** scenario. In 2030, when light-duty electric vehicle sales reach 85%, 1.4 million EVs will be on the road. When light-duty vehicle sales are 100% electric, 3.2 million EVs will be on the road, nearly doubling the amount of EVs on the road in just five years. The same dynamic exists across all vehicle classes. For example, the medium-duty electric vehicle stock rises from just under 16,000 EVs in 2030 to over 264,000 in 2050.

FIGURE 2.

Electric Vehicle Sales and Stock, Clean Car and Truck and No Transportation Action Scenarios

		CLEAN CAR AND TRUCK		NO TRANSPORTATION ACTION	
	Year	**% EV Sales**	**Stock**	**% EV Sales**	**Stock**
Light-Duty Vehicles	2030	85%	1,432,877	6%	183,267
	2035	100%	3,284,746	8%	291,176
	2040	100%	4,926,429	10%	421,441
	2050	100%	6,432,281	14%	702,847
Medium-Duty Vehicles	2030	43%	15,898	0.2%	201
	2035	91%	61,803	0.25%	327
	2040	100%	124,242	0.32%	478
	2050	100%	264,102	0.42%	876
Heavy-Duty Long Haul	2030	22%	1,453	0.2%	38
	2035	46%	5,587	0.2%	57
	2040	50%	10,636	0.3%	77
	2050	50%	17,088	0.4%	119
Heavy-Duty Short Haul	2030	44%	5,615	0.2%	73
	2035	91%	21,601	0.2%	109
	2040	100%	41,144	0.3%	147
	2050	100%	66,207	0.4%	228

FUELS

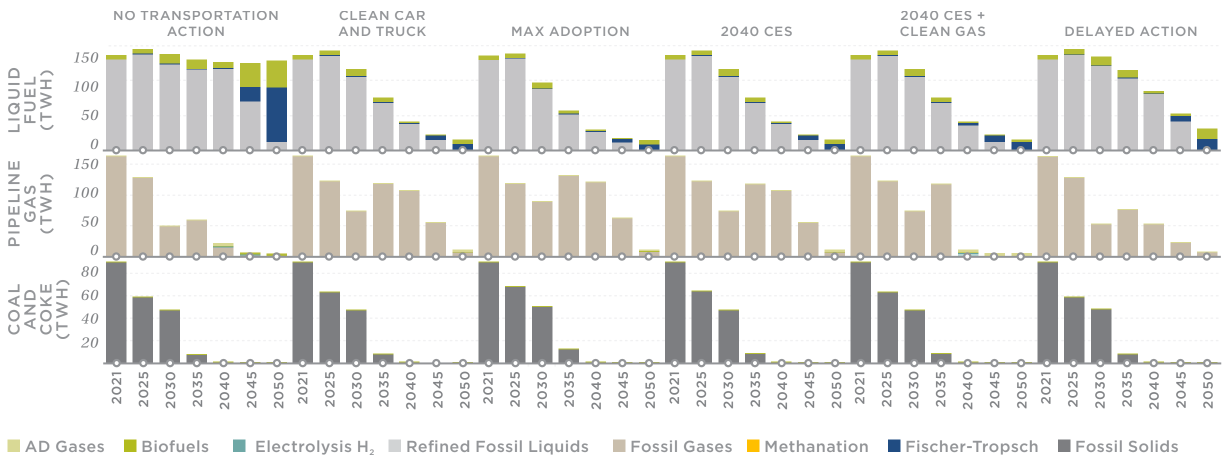
Major fuels, including liquid fuels for use in vehicles, pipeline fuels to serve electricity generation, and coal/coke for electricity generation, vary widely across all scenarios. The **No Transportation Action** scenario maintains significant fuel use, due to the lack of electric vehicle adoption. In contrast, most electrification scenarios include a near elimination of major liquid fuels by 2050. In **No Transportation Action**, new infrastructure — including electrolysis, Fischer-Tropsch processes, methanation, and biofuel production — is required to produce low-carbon fuels to meet emissions goals.[5] Expensive biofuels and increased electricity investments to meet new electrolysis loads significantly drive up costs relative to the electrification scenarios. In the **Core Decarbonization** scenarios, the remaining liquids that fuel a small number of internal combustion or fuel-cell vehicles are also decarbonized via alternative or synthetic drop-in fuels. Limited amounts of gas generation served by pipeline fuel also remain in the final years of the study period and must be decarbonized through the use of low or zero-carbon synthetic fuels or biofuels.

5 Liquid fuels that power ICE vehicles can include conventional oil-based transportation fuels, as well as biomass-derived or synthetic drop-in fuels for liquid gasoline, diesel, or jet fuel. In later years of the analysis, biofuel and synthetic fuel production ramps up in order to produce low- to zero-carbon drop-in fuels for the remaining ICE vehicles on the road. Synthetic fuels are assumed to come from the Fischer-Tropsch process in the analysis, utilizing inputs of CO_2 and hydrogen gas derived from clean electrolysis. Methanation combines hydrogen and CO_2 to produce synthetic gas that is injected into pipelines. More detail can be found in this diagram from the Clean Energy Transition Institute.

The **Delayed Action** scenario presents the risks and costs of moving too slowly on transportation electrification. This scenario delays electric vehicle sales by 10-15 years, such that all vehicle sales are electric by 2050, rather than 2035-2040 as in the other electrification scenarios. By 2050, a significant number of ICE vehicles remain on the road but must be decarbonized due to economy-wide emissions targets. The **Delayed Action** scenario thus has a higher demand for clean fuels, which require costly biofuel and synthetic fuel production infrastructure.

FIGURE 3.

Major Fuels Across Scenarios



ELECTRIC SECTOR

A dramatic acceleration of electric vehicles in Arizona requires commensurate supply-side changes to help serve new energy demands in the clean economy. As of 2021, Arizona generates around 20% of its electricity from coal.[6] In this analysis, we evaluate various pathways to meeting economy-wide energy demands, subject to emissions and clean energy constraints. Four scenarios evaluate meeting electricity demands constrained by the Arizona Corporation Commission's formerly proposed Energy Rules update, which would have required achieving 100% clean electricity by 2070.[7] Another scenario, **2040 CES**, evaluates the impact of an accelerated clean electricity standard (CES), including achieving 80% clean electricity by 2030, and 100% clean electricity by 2040. The **2040 + Clean Gas** scenario evaluates the impact of an accelerated CES with a clean gas requirement by 2040. All scenarios are constrained by an economy-wide emissions constraint of 40% greenhouse gas reduction by 2030 and 100% reduction by 2050, below 2016-2018 baseline levels.

6 State of Arizona ENERGY SECTOR RISK PROFILE

7 Until January 2022, the ACC was considering the adoption of a new goal for Tucson Electric Power, Arizona Public Service, and UniSource Energy Services to achieve 100% clean electricity by 2070.

TABLE 3.

Electricity and Emissions Policy, All Scenarios

SCENARIO	CLEAN ELECTRICITY POLICY	ECONOMY-WIDE GHG POLICY
No Transportation Action	100% CES by 2070 50% CO_2 reduction by 2032 80% CO_2 reduction by 2050 Emissions Baseline 2016-2018 Average	40% GHG reduction by 2030 100% GHG reduction by 2050 Emissions Baseline 2016-2018 Average
Maximum Feasible Adoption	100% CES by 2070 50% CO_2 reduction by 2032 80% CO_2 reduction by 2050 Emissions Baseline 2016-2018	40% GHG reduction by 2030 100% GHG reduction by 2050 Emissions Baseline 2016-2018 Average
Clean Car and Truck	100% CES by 2070 50% CO_2 reduction by 2032 80% CO_2 reduction by 2050 Emissions Baseline 2016-2018	40% GHG reduction by 2030 100% GHG reduction by 2050 Emissions Baseline 2016-2018 Average
Delayed Action	100% CES by 2070 50% CO_2 reduction by 2032 80% CO_2 reduction by 2050 Emissions Baseline 2016-2018	40% GHG reduction by 2030 100% GHG reduction by 2050 Emissions Baseline 2016-2018 Average
2040 CES	80% CES by 2030 100% CES by 2040	40% GHG reduction by 2030 100% GHG reduction by 2050 Emissions Baseline 2016-2018 Average
2040 CES + Clean Gas	80% CES by 2030 100% CES by 2040 Zero-carbon gas required by 2040	40% GHG reduction by 2030 100% GHG reduction by 2050 Emissions Baseline 2016-2018 Average

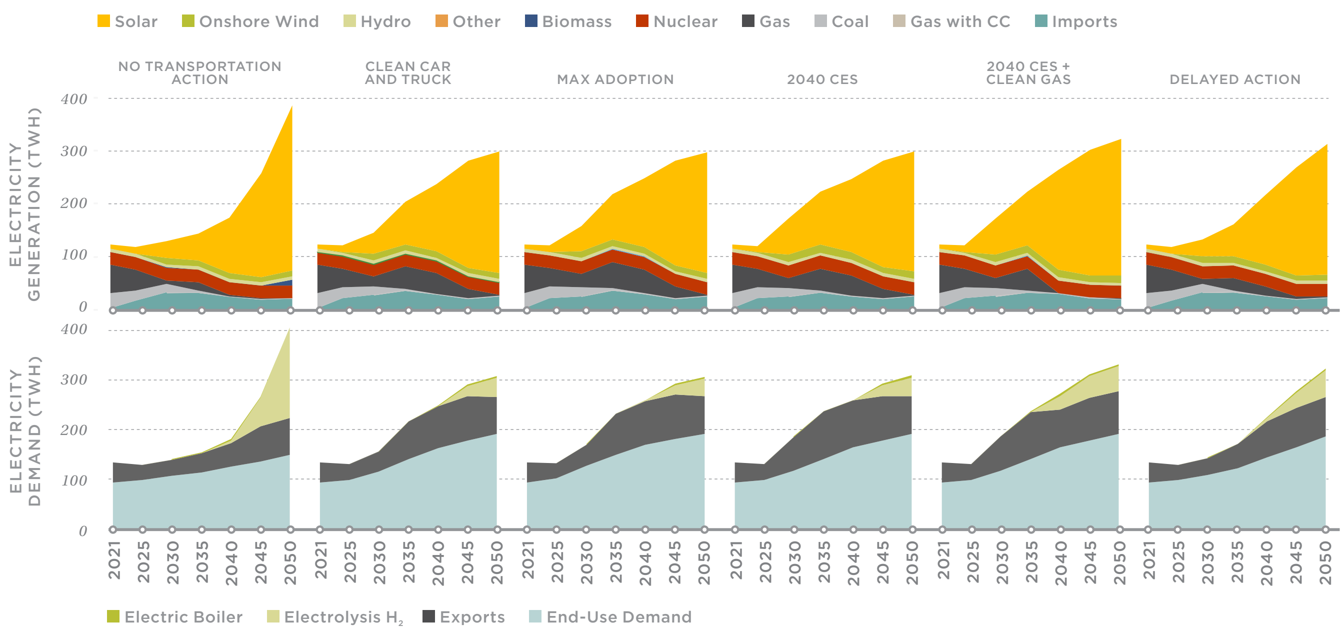
Arizona must significantly ramp up clean electricity generation in order to meet growing energy demand. In the **No Transportation Action** scenario, energy and clean fuels demand is highest, and this results in the largest electricity and hydrogen sectors in the modeled scenarios. Alternatively, in the **Core Decarbonization** scenarios, the switch to electric vehicles reduces the need for clean fuels and a larger electricity sector to produce those fuels. According to EIA, Arizona has the nation's second-highest solar potential.[8] Solar capacity rises sharply from 2030 onwards, cementing solar as the dominant source of energy by 2050 across all scenarios. In the **Clean Car and Truck** scenario, generation capacity in 2050 is 4.5 times the size of 2021 capacity, serving 2.3 times the load. By 2050, the **Clean Car and Truck** scenario builds 77 GW of solar PV and 35 GW of battery storage in Arizona.

8 https://www.eia.gov/state/analysis.php?sid=AZ

In all scenarios, the retirement of coal capacity dramatically reduces emissions, leaving room for additional emissions from gas generation through 2040. Alternatively, the accelerated clean electricity scenarios require an even faster deployment of solar and storage investments, in order to ensure that electricity generation is zero-carbon by 2040. The strengthening of the transmission system between Arizona and surrounding states allows the West access to low-cost and diverse renewable resources and increases the size of the export market opportunity for Arizona. In all scenarios, the model adds 6 GW of transmission capacity between Arizona and California. Arizona becomes a major exporter of clean energy, specifically excess solar power, as the state ramps up its renewable capacity.

FIGURE 4.

Electricity Generation and Demand



EMISSIONS

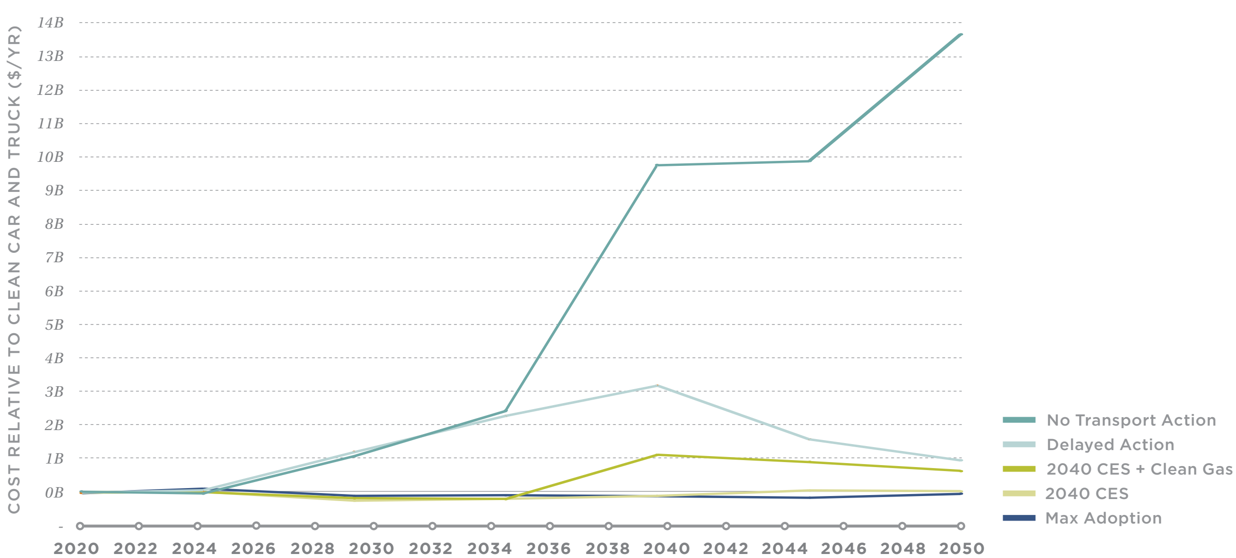
All scenarios modeled in this analysis must meet binding, economy-wide emissions constraints based on a 2016-2018 baseline. In each scenario, economy-wide greenhouse gas emissions are reduced by 40% by 2030 below baseline, and 100% by 2050. In 2021, about 30% of economy-wide emissions are due to coal generation. Elimination of the coal fleet by 2040, based on the planned retirements of the state's major coal generators, thus leads to significant emissions reductions. In those scenarios with rapid decarbonization of both transportation and electricity, there is still room for additional gas generation in the power sector. However, emissions reductions are most significant in a scenario that analyzes both a more stringent 2040 clean electricity standard and a requirement that all pipeline gas is zero-carbon by 2040. In all scenarios, a certain level of geologic CO_2 sequestration, offsetting emissions, is required.

COST

Relative to the **Clean Car and Truck** scenario, taking no transportation action drives up costs dramatically between 2030 and 2050 as ICE vehicles demand more energy, increasingly in the form of clean alternative fuels, compared to EVs. The model sums annualized capital costs and operating costs to present an annual revenue requirement across the entire energy economy. As detailed in Figure 5, scenarios that require a larger electricity system or a dramatic increase in clean fuels relative to the **Clean Car and Truck** scenario are significantly more costly. In **No Transportation Action**, a larger electricity system is required to produce a significant amount of clean fuels to serve a large ICE vehicle fleet and meet the net-zero target, increasing costs significantly. Similarly, a **2040 CES** with a clean gas requirement also necessitates a larger, more costly electric system. The **Delayed Action** scenario yields similar results until 2040, albeit on a smaller scale. The **Maximum Feasible Adoption** scenario, in which electric vehicle sales are accelerated by five years, brings no cost benefits relative to the **Clean Car and Truck** scenario but has potential implications in regard to feasibility and the distributional impacts on individual consumers.

FIGURE 5.

Net Cost Comparison Relative to Clean Car and Truck Scenario

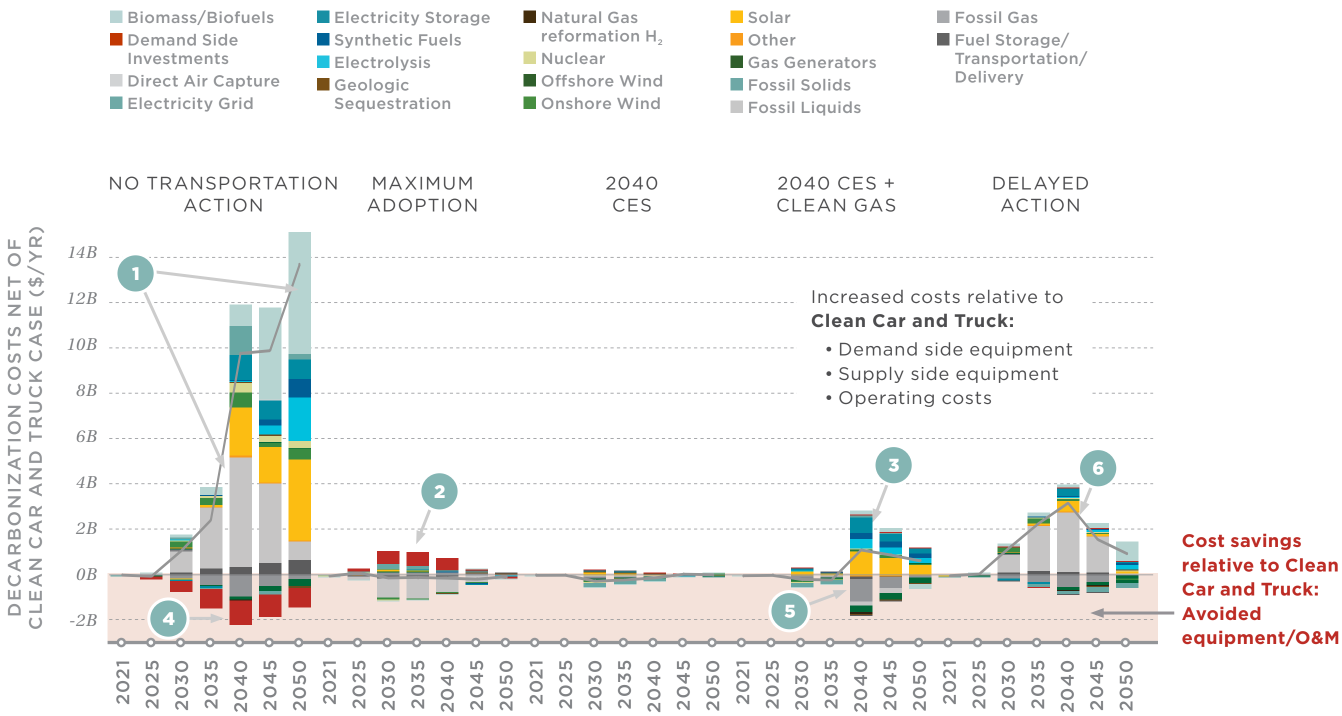


Converting the relative costs of each scenario as a percentage of forecasted state GDP illuminates the scale of the clean energy and transportation transition. By 2050, the **No Transportation Action** scenario reaches 1.9% greater GDP spending than the **Clean Car and Truck** scenario. This corresponds to an additional $13.7 billion in annual energy spending in 2050 compared to the **Clean Car and Truck** scenario. The **Clean Car and Truck** scenario represents the most cost-effective and technically feasible pathway for transportation decarbonization in Arizona.

As Figure 6 details, dramatic cost increases in the **No Transportation Action** scenario suggest that failing to aggressively adopt electric and fuel-cell vehicles will make future decarbonization pathways economically infeasible. Relative to the **Clean Car and Truck** scenario, **No Transportation Action** requires massive spending on electricity generation, electrolysis, and liquid fuels production. While the **Core Decarbonization Scenarios** require increased investment in demand-side measures, such as the purchase of electric vehicles and appliances, there is significantly reduced spending on expensive biofuels and synthetic fuels to power ICE vehicles. Similarly, the **Core Decarbonization Scenarios** include significant cost savings due to a smaller electricity system, which requires less investment in clean energy generation relative to the **No Transportation Action** scenario**.**

FIGURE 6.

Net Costs Graph



OBSERVATIONS

1 No Transport Action increased fossil costs early, and then larger electricity sector and clean fuel costs later

2 Max Adoption offsetting increased demand side costs with decreased gasoline and diesel costs

3 Clean Gas drives additional investment in solar, storage, and electrolysis

4 Decreased fossil gas and demand side equiptment investments

5 Clean gas avoids gas and gas generator costs in 2040 and after

6 Delayed Action avoids some gas but fossil and clean fuels drive up costs

Key Actions for the Next 30 Years to Achieve Transportation and Economy-Wide Decarbonization Goals

- Developing policy initiatives that support transportation electrification needs to begin immediately to achieve stock rollover of demand-side technologies. Early electrification is paramount to avoid large decarbonization costs in the future.
- Retiring coal is Arizona's most impactful near-term path to significant emissions reductions. In 2018, 66% of electric sector emissions and 34% of total economy-wide emissions were due to coal.[9] Policy makers must focus on accelerating coal retirements and curtailing future coal power generation.

9 Carbon dioxide state emissions inventory for Arizona used to calculate the emissions baseline and for 2018 (the most recent published year) taken from EIA (https://www.eia.gov/environment/emissions/state/)

Faster coal retirements than modeled in this analysis may lead to even stronger cost savings.

- Arizona has great access to high quality solar. Investing and planning in new renewable resources to meet anticipated load growth is essential to support further EV initiatives.
- Starting from the 2030s, Arizona must make greater efforts to accelerate solar and battery investments, such that the state has deployed approximately 30 GW of solar PV and 10GW of battery storage by 2035.
- By 2040, Arizona should target 100% clean vehicle sales in light-, medium-, and heavy-duty vehicles, as well as 100% electric appliance sales in buildings.
- Greater regional coordination needs to be explored to facilitate clean energy transfers across the U.S. West. In all scenarios, Arizona increases transmission expansion to export power to California.
- By 2040, investments in electrolysis must increase to support clean fuels production, which will help decarbonize any remaining primary fuel use in all sectors of the economy.
- Electrified and clean end uses should reach close to 100% penetration in most demand-side sectors in the 2040s. Depending on technological advancements over the next 20-30 years, hydrogen may play a significant role in end-use demand.
- By 2050, any remaining emissions will be offset by carbon capture and sequestration.

CONCLUSION

Transitioning away from internal combustion engine vehicles to electric vehicles is critical if Arizona is to meet decarbonization targets and keep energy costs low for consumers. Taking no action to increase electric vehicle penetration will cost nearly $14 billion per year more in 2050 than achieving a fully electrified vehicle stock. Achieving 100% light-duty EV sales by 2035 and 100% medium-and heavy-duty clean vehicle sales by 2040 is cost-effective and enables a pathway to deploy critical clean energy infrastructure to meet rising electricity demand while also building out the necessary charging and related vehicle infrastructure. At the same time, the electric sector must scale up and rapidly decarbonize in order to meet decarbonization targets, beginning with rapid, cost-effective coal retirements. A coordinated approach is required to ensure that long-term electricity planning appropriately incorporates necessary and aggressive economy-wide electrification.