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Discussion Paper

Assessing the Impact of Energy Transition Initiatives on the Policy Cost of Saudi Arabia's Net-Zero Ambition

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Abstract

Saudi Arabia's ambitious goal to achieve a net-zero economy by 2060 offers a unique opportunity for diversification away from fossil fuels while fostering long-term economic resilience and sustainability. Crucial to this transition are energy policies that steer the Kingdom from a fossil-fuel-based economy toward carbon neutrality. Using GCAM-KSA, a multi-sectoral integrated assessment model tailored to Saudi Arabia's economic and energy systems, this study evaluates the impact of early energy transition initiatives on the policy costs of achieving the net-zero target in Saudi Arabia. Insights from the study indicate that early action in the form of current and proposed energy initiatives has the potential to reduce the inertia associated with the adoption of low-carbon technology. Consequently, this reduces the economic burden associated with the net-zero transition. Comparing the cost estimates of early action to a scenario of delayed implementation reveals significant long-term net benefits, with policy cost reductions ranging from 38% to 72%. This highlights that early action energy system initiatives have the potential to reduce the economic burden associated with the net-zero transition. These findings offer valuable insights into how current and planned energy policies can mitigate the economic challenges associated with Saudi Arabia's transition to a net-zero economy.

Keywords: Net Zero, Energy Transition, Climate Policy.

1. Background and Introduction

The global shift toward a net-zero economy represents an important response to mitigating the adverse impacts of human-induced climate change (UNEP 2021). Nations across the globe are setting forth ambitious objectives aimed at attaining net-zero emissions within specified timeframes. Currently, countries with net-zero targets cover about 88% of global emissions, 92% of the global Gross Domestic Product, and 89% of the global population (Net Zero Tracker 2024). Nevertheless, it is imperative to understand that despite these shared aspirations, each country's journey to net zero is distinct, and the challenges that different countries confront can vary significantly.

In 2021, the Kingdom of Saudi Arabia (KSA) made a significant commitment to combat climate change by setting a target to achieve net-zero greenhouse gas (GHG) emissions by 2060, alongside its National Determined Contribution (NDC) goal of reducing emissions by 278 MtCO2e by 2030. KSA's unique position as a prominent energy exporter in the global energy landscape underscores the significance of its commitment to a net zero target. This transition will undoubtedly pose a significant transition risk due to the Kingdom's heavy reliance on hydrocarbon revenue (Belaïd and Al Sarihi 2022). However, amid these challenges, there is a compelling landscape of potential opportunities. First, Saudi Arabia's resilient economic growth, coupled with its untapped innovation potential (IMF 2023), makes its journey towards a net-zero economy exceptionally promising. Second, this transformation is set to play a pivotal role in Saudi Arabia's efforts to diversify its economy away from hydrocarbons while promoting economic stability and fostering sustainable growth.

The energy sector of Saudi Arabia is currently responsible for nearly 80% of the country's total greenhouse gas emissions (Gütschow and Pflüger 2023; Alsarhan and Zatari 2022). The significant emissions from this sector highlight the critical need for transitioning to cleaner energy sources to reach net-zero emissions. To navigate the challenges inherent in this energy transition, Saudi Arabia has implemented a range of forward-looking policies. One of the most significant initiatives is the Saudi Vision 2030 plan, which seeks to diversify the Kingdom's economy by reducing its dependence on oil and fostering a more resilient economic future (IMF 2023). In line with this vision, Saudi Arabia has implemented two notable energy price reforms in 2016 and 2018 (SGI 2021). These reforms were aimed at encouraging efficient energy consumption by aligning electricity, gasoline, and diesel prices more closely with international prices (Aldubyan and Gasim 2021). Within this, the KSA also aims to achieve a power system that comprises 50% renewable technologies and 50% natural gas by 2030.

Saudi Arabia has embraced the circular carbon economy (CCE) approach, aimed at reducing greenhouse gas emissions and driving the energy transition to combat climate change (Shehri et al. 2023). A core pillar of the CCE approach is to reduce energy demand through efficiency improvements. With this goal, the Saudi Energy Efficiency Program (SEEP), which was initiated in 2012, has played a key role in Saudi Arabia's CCE commitment. SEEP has already made significant strides in promoting efficiency in various sectors such as industry, buildings, and transportation (Belaïd and Massié 2023). In industry, SEEP focuses on enhancing energy conservation practices in key manufacturing sectors, such as iron production, cement factories, and petrochemical facilities. In the building sector, the government has introduced energy efficiency labels, stringent standards, and regulations (Al-Tamimi 2017). Moreover, government buildings are undergoing retrofits to lower energy consumption and emissions (SEEC 2021). Saudi Arabia has also launched several transportation sector initiatives, including energy efficiency labels for vehicles, tire standards, and the enforcement of Corporate Average Fuel Economy (CAFE) standards (Sheldon and Dua 2021).

Numerous empirical and modeling studies have investigated the implications of energy transition policies in Saudi Arabia. Table 1 presents a selection of noteworthy journal and report publications about Saudi Arabia's energy transition policies. Empirical studies including Atalla, Gasim and Hunt (2018), Sheldon and Dua (2021), and Bah and Saari (2020) have assessed the effects of the energy price reforms (EPR) on various fronts, and these include energy demand reduction and associated benefits, such as emission reduction and welfare gains. In the same vein, studies including Groissböck and Pickl (2018) and Matar (2017) have applied energy and engineering models to gauge the impact of the energy price reforms. Furthermore, insights from studies such as Abd-ur-Rehman et al. (2018), Al Garni, Awasthi, and Ramli (2018), Krarti and Aldubyan (2021) and Krarti, Aldubyan, and Williams (2020) offer a comprehensive assessment of the economic and environmental consequences of building energy efficiency improvements within Saudi Arabia. In a related context, Belaïd and Massié (2023) employed an econometric model to evaluate the impact of economy-wide energy efficiency enhancements on carbon intensity in Saudi Arabia. Other energy modeling studies, including Alshammari and Sarathy (2017), Alshammari (2021), Elshurafa and Peerbocus (2020), and Elshurafa et al. (2021), have investigated the role of low-carbon solutions in decarbonizing Saudi Arabia's power and energy sectors. Several advanced general equilibrium studies, including those by Durand-Lasserve (2023), Blazquez et al. (2020, 2021), and Almutairi et al. (2024), have examined the interplay between the Saudi economy and global energy markets, with a focus on understanding how domestic policies and international trends shape economic stability and growth in Saudi Arabia. Collectively, the studies provide valuable insights into the pivotal role played by energy policy instruments and advanced technologies in steering the nation's energy transition journey.

Table 1. Review of the literature on Saudi Arabia's energy transition policies.

Study	Sectoral/Policy Scope	Method	Notable Policy Insight
Abd-ur-Rehman et al. (2018)	Building energy efficiency and renewables	Energy model	Adopting International Energy Conservation Code standards and incorporating solar technologies in Saudi homes can significantly reduce energy consumption.
Al Garni, Awasthi, and Ramli (2018)	Buildings and renewables	Energy model	Advanced solar panel tracking systems can boost power generation and cut costs for grid-connected solar PV systems.
Aldubyan and Gasim (2021)	Energy price reform	Econometrics model	Saudi Arabia's recent reforms led to price and income inelasticity in energy demand, resulting in significant welfare gains and reduced consumption.
Alshammari and Sarathy (2017)	Economy-wide decarbonization	Energy model	Achieving an 80% reduction in greenhouse gas emissions from the power generation sector requires implementing energy efficiency measures to enable a smooth transition to a low-carbon energy system.
Alshammari (2021)	Chemical sector decarbonization	Energy model	Tackling industrial sector emissions, especially in chemical manufacturing, is crucial for climate action, and reaching this goal may involve a blend of carbon capture and solar tech.
Atalla, Gasim, and Hunt (2018)	Energy price reform	Econometric model	Raising domestic energy prices in Saudi Arabia, particularly for gasoline, may not substantially curb demand due to price inelasticity. Thus, there's a need to improve energy efficiency and encourage alternative transportation modes.

Study	Sectoral/Policy Scope	Method	Notable Policy Insight
Bah and Saari (2020)	Energy price reform	Input-output model	Energy price reforms in Saudi Arabia disproportionately burden low-income households due to higher energy-intensive product costs.
Belaïd and Massié (2023)	Economy-wide energy efficiency	Econometric model	Economy-wide energy efficiency holds a pivotal role in Saudi Arabia's journey toward achieving its net-zero emissions goal, potentially contributing up to one-fifth of decarbonization by 2060.
Elshurafa and Peerbocus (2020)	Transport electrification (electric vehicles)	Energy model	Adopting a low- or no-carbon energy source for charging electric vehicles in Saudi Arabia to ensure emissions reduction.
Elshurafa et al. (2021)	Power sector decarbonization	Energy model	In Saudi Arabia, renewable deployment can defer national gas supply expansion plans but not investments in expanding domestic gas transport capacities.
Groissböck and Pickl (2018)	Energy price reform	Energy model	Saudi Arabia's power generation expansion should consider fuel-price reforms to minimize emissions, aiming for domestic retail prices above 20% of expected international wholesale fuel prices.
Krarti and Aldubyan (2021)	Building energy efficiency and decarbonization	Energy model	Substantial cost-effectiveness can be achieved by reducing electrical loads through energy efficiency measures in individual housing units.
Krarti, Aldubyan, and Williams (2020)	Building energy efficiency and decarbonization	Energy model	Implementing energy retrofit programs tailored to different types, ages, and locations of residential buildings in Saudi Arabia can improve cost-effectiveness and yield multiple benefits.
Krarti, Dubey, and Howarth (2017)	Building energy efficiency and decarbonization	Energy model	Energy efficiency programs in Saudi Arabia's building sector, such as retrofits and optimized new designs, can result in significant energy savings, cost reductions, and positive environmental gains.
Matar (2017)	Electricity pricing	Energy model	Time-of-use (TOU) pricing in Saudi Arabia's electricity sector can potentially influence household electricity consumption patterns and have wider economic effects.
Matar et al. (2017)	Energy price reform	Energy model	Alternative energy policies, such as deregulating fuel prices and incentivizing renewables, can lead to a more efficient energy system in Saudi Arabia, reducing oil and gas consumption and fostering economic growth.
Matar et al. (2023)	Economy-wide decarbonization	Energy model	A non-prescriptive scenario without energy price reform can achieve equivalent emission reduction at a lower cost compared to the announced policies scenario.
Sarrakh et al. (2020)	Energy price reform	Price-gap analysis	Saudi Arabia's energy subsidies, though initially aligned with socio-economic objectives, may hinder progress due to over-subsidization and poor implementation.
Sheldon and Dua (2021)	Energy price reform	Econometric model	Saudi Arabia's vehicle fuel economy improvement is influenced by gasoline price elasticity, with the potential for progressive policies like feebates targeting income and household size.
Qiu et al. (2024)	Economy-wide decarbonization	Integrated assessment model	Early deployment of direct air capture (DAC) driven by its early and rapid cost reduction could reduce climate mitigation costs relative to delayed DAC deployment.
Durand-Lasserve (2023)	Energy price deregulation and global oil market	General equilibrium model	Saudi Arabia's path to net-zero emissions will be shaped by the deregulation of energy prices and the implementation of CO_2 caps, both essential for cutting carbon emissions and advancing sustainable energy technologies.
Almutairi et al. (2024)	Energy price and global oil market	General equilibrium model	Saudi Arabia's Vision 2030 enhances economic resilience to oil shocks by 10% to 60% through diversification and structural reforms, despite increasing volatility from changes in energy prices and tax policies.
Blazquez et al. (2021)	Energy price and global oil market	General equilibrium model	Saudi Arabia's Vision 2030 reforms, encompassing VAT introduction, energy price adjustments, and renewable energy deployment, collectively boost GDP and welfare, with energy price reforms showing the most substantial benefits.
Blazquez et al. (2020)	Energy price and global oil market	General equilibrium model	Saving domestically consumed oil in Saudi Arabia offers significant economic efficiencies by capitalizing on the price differences between domestic and international markets.

Although previous studies on Saudi Arabia's energy transition have been valuable in enhancing our understanding of the journey toward a sustainable energy landscape, these studies are often limited in their scope of addressing the challenges and opportunities inherent in achieving net-zero emissions. Many of these studies tend to focus on specific facets of the transition, such as energy price reforms or sectoral decarbonization, thus missing key interactions and feedback across policies. In turn, the lack of sufficient representation of inter-sectoral interactions and feedback in previous studies has resulted in a gap in the holistic understanding of the country's net-zero pathway. Furthermore, most of these studies have a short- to medium-term focus, thereby overlooking the long-term implications associated with energy policy instruments.

This research aims to address the existing gaps by evaluating Saudi Arabia's energy transition, with a focused examination of the economic implications of current and prospective policies. The study focuses on the consequences of early intervention in the energy sector by assessing both existing and planned measures in terms of their financial impact. Additionally, it aims to shed light on the potential strategies to minimize economic losses by taking proactive mitigation actions within the energy system. Overall, this study offers actionable insights into how energy transition policies can steer the Saudi economy toward a more economically efficient net-zero pathway. To achieve this objective, the study utilizes a regionalized variant of the integrated model assessment tool known as the Global Change Analysis Model (GCAM v6). This model (dubbed GCAM-KSA) is tailored to capture the unique characteristics and dynamics of Saudi Arabia's economy and energy systems. The study is structured as follows: Section 2 provides an in-depth explanation of GCAM-KSA, followed by highlighting the scenarios and their associated assumptions. Subsequently, the study delves into a discussion of the findings, focusing on primary energy and emissions transformations under alternative baseline scenarios. Finally, an exploration of net-zero emissions and their policy cost implications across various scenarios is conducted.

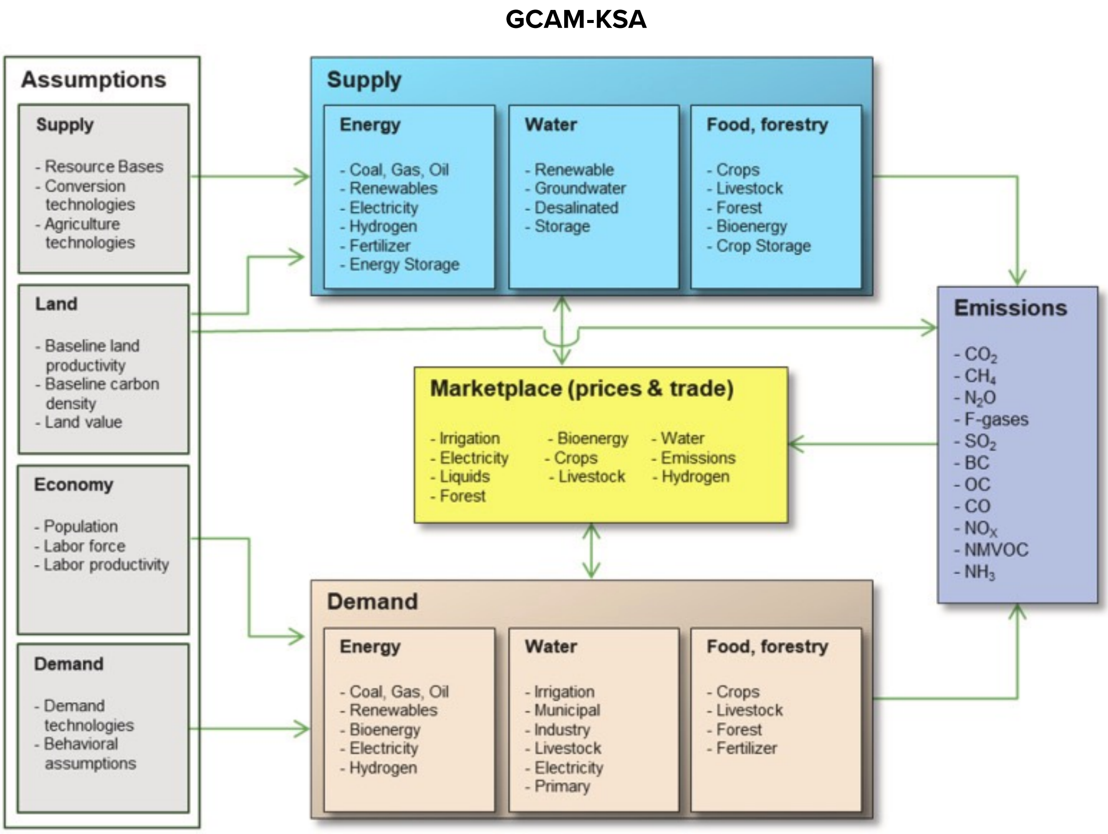
2. Methods

2.1 GCAM-KSA

To address the objectives of this paper, the study employs a regionalized version of the Global Change Analysis Model (GCAM v6) known as GCAM-KSA (Kamboj et al. 2024). Building upon the technology-rich framework of GCAM v6, GCAM-KSA is tailored to capture the unique characteristics and dynamics of Saudi Arabia's economy and energy systems. While GCAM v6 provides detailed representations of water, agriculture, and land use systems, it is important to note that the version of GCAM-KSA used in this study primarily focuses on the representation of KSA's energy systems and the resultant emissions.

In GCAM-KSA, KSA is portrayed as a distinct geopolitical region alongside the existing 32 geopolitical regions of GCAM v6. The detailed representation of the KSA energy system encompasses (see Figure 1) the production of energy resources (i.e., oil, gas, uranium, and renewables), energy transformation and distribution (electricity, refining, gas processing, and hydrogen production), and final energy-demand sectors (buildings, industry, and transportation). The model tracks the emission of 24 different gases along the supply chain of the energy system from production through to final energy services. These gases include CO2, N2O, CH4, and F-gases, as well as short-lived species and ozone precursors.

Figure 1. GCAM-KSA schematic representation of the energy system.



Source: Kamboj et al. (2023).
Note: CNG = compressed natural gas; LPG = liquified petroleum gas.

Similar to GCAM v6, GCAM-KSA operates in five-year intervals, beginning with the calibration year of 2015 and continuing until 2100. During each time step, the model iterates until it identifies a set of prices that effectively balances all markets and meets all consistency requirements. As a dynamic recursive model, GCAM determines technology and market decisions by considering prevailing prices. Further, technology decisions are determined by a logit formulation, which allocates market share to technologies based on their levelized costs mediated by the influence of non-cost factors, such as societal preferences, existing infrastructure, non-cost barriers to market entry, and many more (Calvin et al. 2019; Clarke and Edmonds 1993; McFadden 1973). This formulation mimics decision-making processes among competing technologies, with technology options ranked according to the calibrated preferences regarding relative technology costs (Calvin et al. 2019).

2.2 Mitigation Cost Computation in GCAM-KSA

This study aims to quantify the policy costs associated with net-zero scenario strategies of Saudi Arabia. GCAM employs a "deadweight loss" approach to estimate the welfare losses resulting from these climate policies. In this context, the deadweight loss refers to the loss of economic efficiency when the equilibrium outcome is not achievable due to market distortions, typically caused by suboptimal outcomes of policy interventions (Stern 2007). Notably, GCAM's policy cost calculations focus on the gross costs – that is, the computation excludes the benefits of mitigation and the social and resource costs incurred by implementing the policy (Iyer et al. 2015). Instead, it quantifies deadweight loss by measuring the costs incurred to meet GHG mitigation targets (Calvin et al. 2014). GCAM calculates policy costs by calibrating the marginal abatement cost for each period based on an endogenously calculated carbon price and the level of GHG emissions abated due to technology and socio-economic dynamics (Peng et al. 2021). By default, GCAM calibrates the marginal abatement curve across five carbon price margins (0%-20%, 20%-40%, 40%-60%, 60%-80%, and 80%-100%) for each period. The deadweight loss at each level is determined by the impact of the carbon price on emissions relative to an emission pathway without a carbon price (Chaturvedi and Shukla 2014) (see Figure 1a in the Appendix). The carbon price levels (i.e., P) at the margins and the corresponding abated GHG emissions (E) form the marginal abatement cost curve for a given period (T). The mitigation cost (CT) for a given period is then determined by computing the area under the curve. Specifically, this is done by integrating the carbon price, as a function of abated emissions, over the emissions range that is affected by the policy (see equation 1). The cumulative policy cost is calculated by interpolating the estimated mitigation costs between time steps, discounting them using a rate "r", and summing them up to the target year (see Equation 2).

$$C_T = \int P(E)\, d(E) \qquad (1)$$

$$Total\ Policy\ Cost = \sum_{T=2025}^{2060} \frac{C_T}{(1+r)^{T-2025}} \qquad (2)$$

2.3 Scenario Design

This study evaluates three distinct energy system scenarios based Saudi Arabia's current and proposed energy transition policies (see Table 3). Each scenario is analyzed under both a baseline and a climate policy trajectory, resulting in a total of six scenarios, which are shown in Table 2. This approach enables a comprehensive examination of the long-term impacts of various policies and mitigation strategies on Saudi Arabia's energy system. Under the baseline trajectory (i.e., Base), we explore the dynamics and outcomes of the energy systems without stringent decarbonization efforts or emissions constraints. Conversely, the climate policy pathways (i.e., NZE) incorporate GHG emissions constraints aimed at achieving a reduction of 278 MtCO2e by 2030, which is consistent with Saudi Arabia's NDC target, and set a course for a linear decline to net-zero emissions by 2060. Assumptions for non-KSA regions meeting their NDC targets and net-zero commitments are based on the framework provided by Ou et al. (2021).

Table 2. Scenario matrix of energy system assumptions and emission pathways.

		KSA Energy Transition Assumptions		
		Delayed Action	**Early Action**	**Early Action+**
KSA Climate Policy Assumptions	**Baseline Assumptions:** • No Climate-Focused Policies: There are no policies or interventions targeting climate change. • Market-Driven Technology Adoption: Energy system technologies evolve based on market factors like cost, consumer preference, and innovation.	Baseline & Delayed Action **(DA_Base)**	Baseline & Early Action **(EA_Base)**	Baseline & Early Action + **(EA+_Base)**
	Net-Zero Assumptions: • Comprehensive Decarbonization by 2060: Strategies are enacted to meet NDC and achieve net-zero GHG emissions by 2060. • Carbon Pricing as a Catalyst: Carbon pricing mechanisms are key drivers of technological advancements in the energy sector.	Net-Zero & Delayed Action **(DA_NZE)**	Net-Zero & Early Action **(EA_NZE)**	Net-Zero & Early Action + **(EA+_NZE)**

Source: Authors.

For the energy system policy assumptions considered, the first scenario, known as the delayed action (i.e., DA) scenario, serves as the basis against which we compare other scenarios. In this scenario, we assume that KSA has not implemented any energy transition energy system policies. This is achieved by excluding recent energy transition measures, such as energy efficiency enhancements, and harmonizing end-use energy prices to represent a trajectory of no price reform. In addition, this scenario envisions a future without support for low-carbon technologies, where traditional hydrocarbons continue to drive future development. The DA scenario provides the context for evaluating the impact of the other two energy policy scenarios.

Table 3. Energy transition scenario element.

Sectors	Policy Instruments	DelayedAction	EarlyAction	EarlyAction+
Power generation sector	Retiring all liquid generation by 2030	✗	✓	✓
	Electricity price reforms	✗	✓	✓
	50% Gas and 50% renewables add capacity from 2025 onward	✗	✓	✓
	Availability of nuclear	✗	✓	✓
Transportation [domestic passenger and in-land freight]	SEEP CAFE standards	✗	✓	✓
	Achieve 25% EV market share for new car sales in Riyadh by 2030.	✗	✗	✓
	Retail price reforms	✗	✓	✓
	Increase public transport by 30% by 2060.	✗	✗	✓
Building [commercial and residential]	Minimum energy performance standard for appliance	✗	✓	✓
	Retail price reforms	✗	✓	✓
	rooftop PV	✗	✓	✓
Industry	Wholesale price reforms	✗	✓	✓
	Energy efficiency improvement (2%/yr)	✗	✗	✓

Note : Red cross mark represents "no" and green check mark represent "yes"

Source: Adapted from Kamboj et al. (2023).

The early action energy system assumptions (i.e EA) incorporate the existing energy system policies currently in effect and announcements made before 2021. Within this scenario, we consider the advantages stemming from various energy efficiency measures initiated under SEEP (see Table A2 in the Appendix regarding the efficiency). In the building and transportation sectors, efficiency improvements are modeled by calibrating the input-output ratio parameters for each end-use sector to reflect various sectoral efficiency targets. The study also models the impact of the two rounds of energy price reforms across all end-use sectors by harmonizing the model price signals with the prevailing energy prices in Saudi Arabia. For the power sector, the study models the objective of achieving a balanced power capacity between renewable and gas-based electricity by 2030 while phasing out liquid fuel-based generation.

Lastly, the enhanced early action (i.e., EA+) scenario represents an extension of the early action scenario. It incorporates additional prospective energy system policies that KSA is considering as part of ongoing efforts to facilitate the Kingdom's energy transition. These enhancements cover various aspects, including industrial energy efficiency (SEEC 2022), electric vehicle (EV) deployment (SIDF 2022), and upscaling of public transportation (RCRC 2023). See Table A4 in the Appendix for cost assumptions applied to EVs and Table A5 for the adjustment in the public transportation load factor to reflect these policies.

This study applies a consistent set of assumptions regarding socio-economic dynamics across all six scenarios. These assumptions align with the SSP2 (middle-of-the-road) narrative. In this scenario, the world follows a path in which social, economic, and technological trends do not shift markedly from historical patterns (Fricko et al. 2017). It should be noted that our modeling exercise accounts for the effects of the COVID-19 pandemic on GDP growth during the period from 2015 to 2020 (see Table A1 in the Appendix).

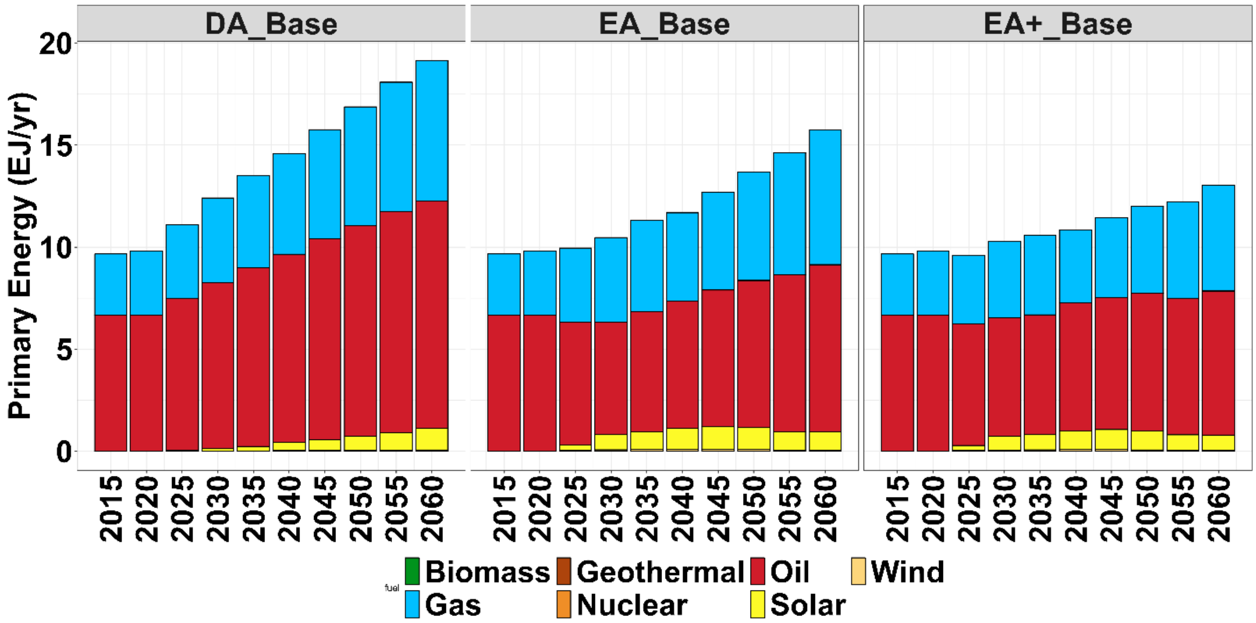
3. Results and Discussion

The results section is structured as follows: Sections 3.1 and 3.2 examine the results related to the baseline scenarios, including DA_Base, EA_Base, and EA+_Base. These sections also explore the interactions among individual policy instruments and highlight the mitigation gaps and the energy system inertia associated with achieving Saudi Arabia's NDC and net-zero targets. In Section 3.3, we analyze the trajectories for residual and negative emissions in the DA_NZE, EA_NZE, and EA+_NZE scenarios, and discuss the policy costs associated with each pathway.

3.1 Baseline Primary Energy Trajectory

Figure 2 presents the projected primary energy mix for the baseline scenarios from 2015 to 2060. In the DA_Base scenario, socio-economic dynamics within the Kingdom are projected to drive a two-fold increase in primary energy demand by 2060 compared to 2015 levels. In this context, Saudi Arabia continues to rely heavily on oil and natural gas resources, which are expected to account for about 94% of the energy mix by 2060. Due to the prevailing economic competitiveness of solar, this technology is projected to gradually expand its share, reaching approximately 5% of the primary fuel mix by 2060.

Figure 2. Primary energy trajectory for DA_Base, EA_Base, and EA+_Base scenario under the baseline assumptions.



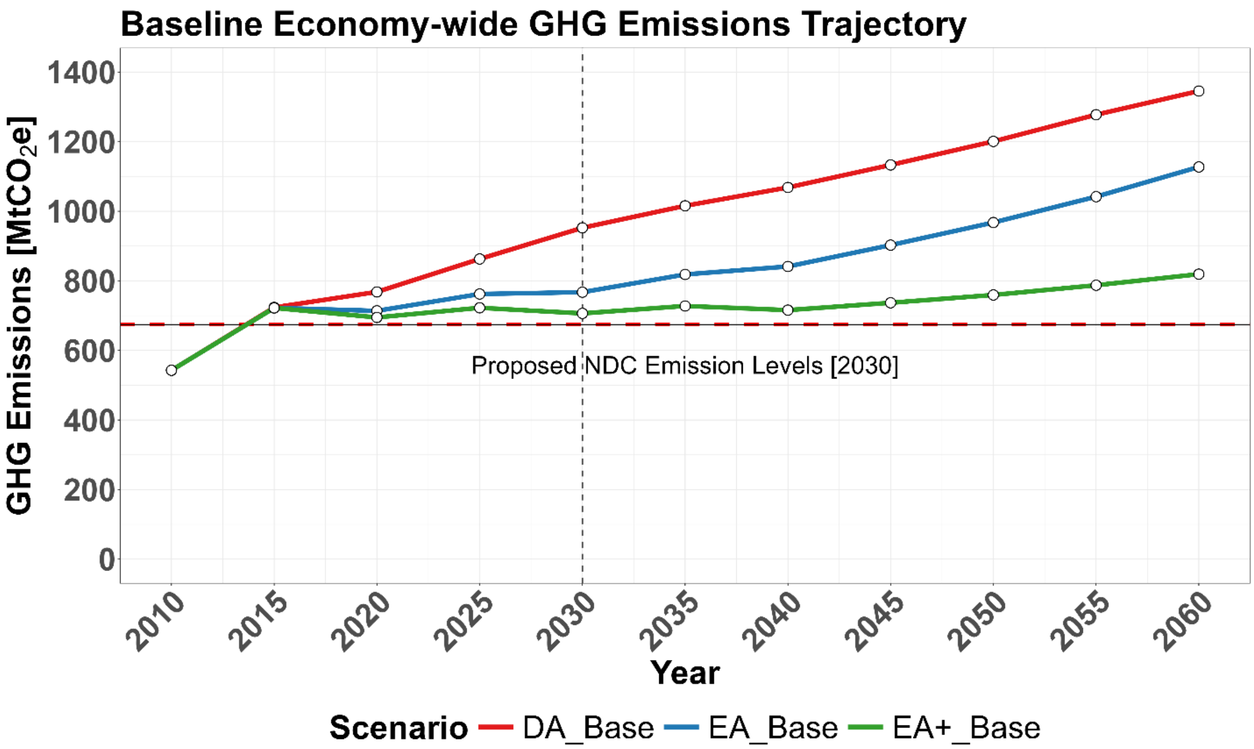
Source: Authors.

Under the EA_Base and EA_Base+ scenarios, Saudi Arabia's projected demand for oil and gas resources is expected to decrease compared to the DA_Base scenario due to the implementation of energy transition policies. Notably, the reduction is more pronounced for oil compared to the decrease in gas consumption. This result aligns with Saudi Arabia's ongoing commitment to transition away from the domestic use of refined oil resources, thereby reducing the carbon footprint associated with oil. In addition, the use of renewable resources, specifically solar energy, is projected to significantly increase in both early action (i.e., EA_Base and EA_Base+) scenarios compared to the delayed action scenario. By 2060, non-fossil resources are projected to account for approximately 6% in the EA_Base scenario and about 7% in the EA_Base+ scenario of the overall primary energy mix. Furthermore, the implementation of sectoral efficiency improvements and EPR policies in the early action scenarios are projected to reduce primary energy demand. By 2030, these policies are projected to achieve efficiency gains a 15.6% (-1.95 EJ) reduction in primary energy consumption for EA_Base and a 25.3% (i.e., 3.14 EJ) reduction for EA_Base+ compared to the DA_Base scenario. Looking toward the long term, by 2060, these efficiency gains are projected to become even more pronounced, resulting in a substantial 17.7% reduction for EA_Base and a remarkable 44.5% reduction for EA_Base+ in primary energy demand compared to the DA_Base scenario.

3.2 Baseline Greenhouse Gas Emissions Trajectory

Figure 3 illustrates the baseline greenhouse gas (GHG) emissions trajectory for the energy system assumptions. In the DA_Base scenario, GHG emissions are projected to increase from 722.2 MtCO2e in 2015 to 1345.6 MtCO2e by 2060. Comparing the early action scenarios to the delayed action scenario reveals significant potential for emissions reduction in the Kingdom of Saudi Arabia. In the near term (i.e., 2030), these policies are projected to result in a decrease of 185 MtCO2e for the EA_Base scenario and 246.0 MtCO2e for the EA_Base+ scenario. However, these projected short-term reductions do not fully align with the Kingdom's 2030 NDC target. This discrepancy is due to the study's focus solely on the energy system, without considering all the key initiatives proposed in the NDC. In the long term (i.e., 2060), emission reductions become more substantial compared to 2030, with a decrease of approximately 218.2 MtCO2e for EA_Base and 526.3 MtCO2e for EA_Base+.

Figure 3. Baseline economy-wide GHG emissions trajectory for DA_Base, EA_Base and EA+_Base scenarios.

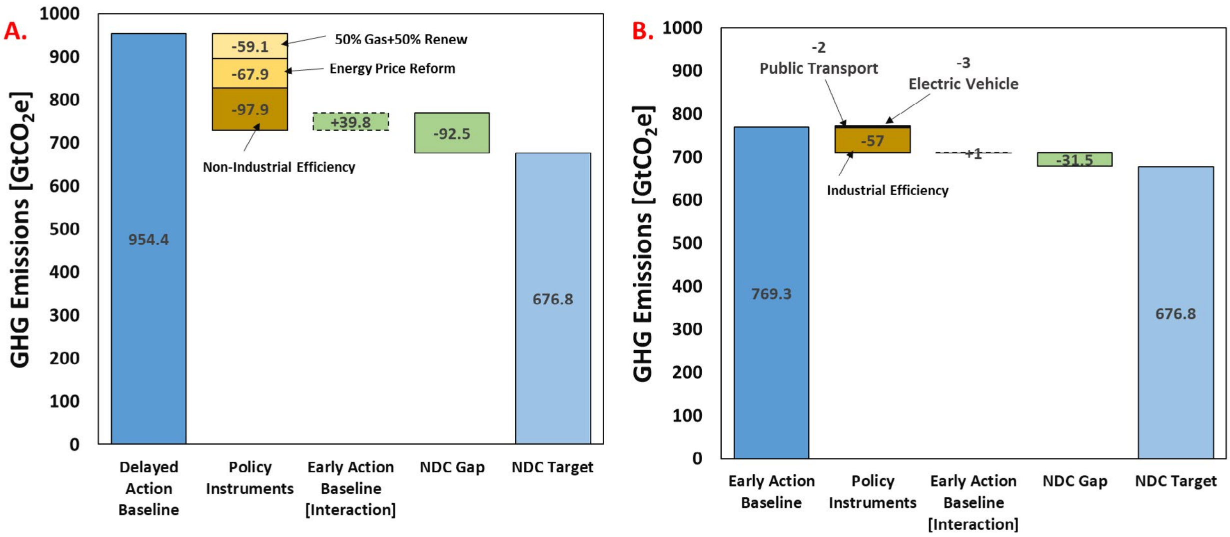


Source: Authors.
Note: The red dashed lines represent the 2030 NDC emissions levels of 278GtCO2. from the DA_Base baseline scenario.

3.2.1 Short-Term Emission Implications of Policy Levers

To provide perspective on the NDC gap under early action baseline scenarios, Figure 4 illustrates the impacts of individual policy instruments and highlights how they interact to achieve economy-wide emission reductions within KSA. Figure 4a details the individual policies and how they interact in the EA_Base scenario compared to the DA_Base scenario. Figure 4b provides a similar breakdown for the policy levers in the EA+_Base scenario compared to the EA_Base scenario.

Figure 4. (a) Effect of individual policies and interaction for EA_Base in reference to DA_Base; (b) Effect of individual policies and interaction for EA+_Base in reference to EA_Base.



Source: Authors.

From Figure 4a, it is evident from the model projections that non-industrial (i.e., building and transportation) efficiency policies are the most effective among the various policy levers. These policies are expected to result in a significant reduction of 97.9MtCO$_2$e emissions per annum in 2030 compared to the DA_Base scenario. The energy price reform is also projected to lead to a reduction of around 67.9 MtCO$_2$e per annum in 2030. Further, Saudi Arabia's plan of having a 50% renewable power capacity and 50% gas-based power as a standalone policy is projected to yield a reduction of about 59.1 MtCO$_2$e per annum in 2030. The relatively moderate effect observed in the power sector policies can be attributed to the absence of stringent climate policies that would encourage a more aggressive phase-down of fossil fuels. In this baseline trajectory, the adoption and integration of cleaner technologies are primarily driven by economic competition void of any carbon policy interventions. Consequently, the deployment of gas power occurs without CCS, which limits the emission reduction potential of this policy.

The combined interaction effects of the individual policies in the EA_Base scenario resulted in a net increase of 39.8 MtCO2e per annum in 2030 compared to the summation of their individual impacts. This outcome reveals the intricate interplay and constraints among specific policies. When combined, these policies may unexpectedly introduce limitations and trade-offs that hinder their individual emissions reduction potential. Additionally, in some cases, the combined policies exhibit diminishing marginal returns, where the cumulative impact falls short of the sum of their individual emissions reduction potentials. Nonetheless, it is crucial to emphasize that the combined effect of the policy interactions surpasses the potential of individual policies in isolation. This implies that the Saudi government's comprehensive energy transition strategy has the potential to yield significant and far-reaching results.

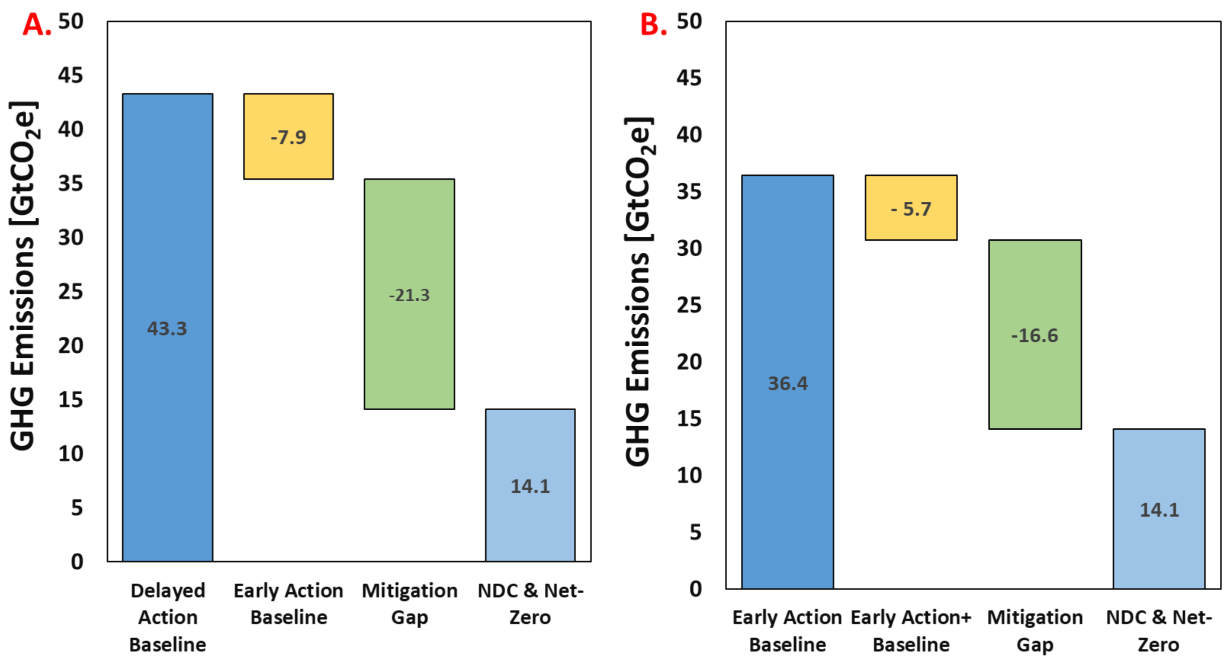
The introduction of public transportation and the scaling up of electric vehicles (EVs) have the potential to reduce emissions by 2 and 3 MtCO$_2$e per year in 2030, respectively, compared to the EA_Base scenario.

These modest estimates are due to conservative assumptions in our scenario design. Strengthening industrial energy efficiency has the potential to lower emissions by 57 $MtCO_2e$. Interestingly, the interaction effect stemming from these individual policies results in a modest net increase of 1 $MtCO_2e$. These enhanced policies can help narrow the Kingdom's National Determined Contributions (NDCs) gap but still fall short of reaching the goal.

3.2.2 Mitigation Gap Analysis

Figure 5 below provides a concise overview of cumulative emissions (i.e., carbon budget) of the three scenarios under baseline trajectory in comparison to an idealized NDC and net-zero decarbonization pathway. This graph aims to illuminate the technological inertia inherent in the early action scenarios by underscoring the magnitude of the mitigation effort needed for Saudi Arabia to achieve the net-zero pathway.

Figure 5. (a) Breakdown of mitigation gap for EA_Base in reference to DA_Base; (b) Breakdown of mitigation gap for EA+_Base in reference to EA_Base.



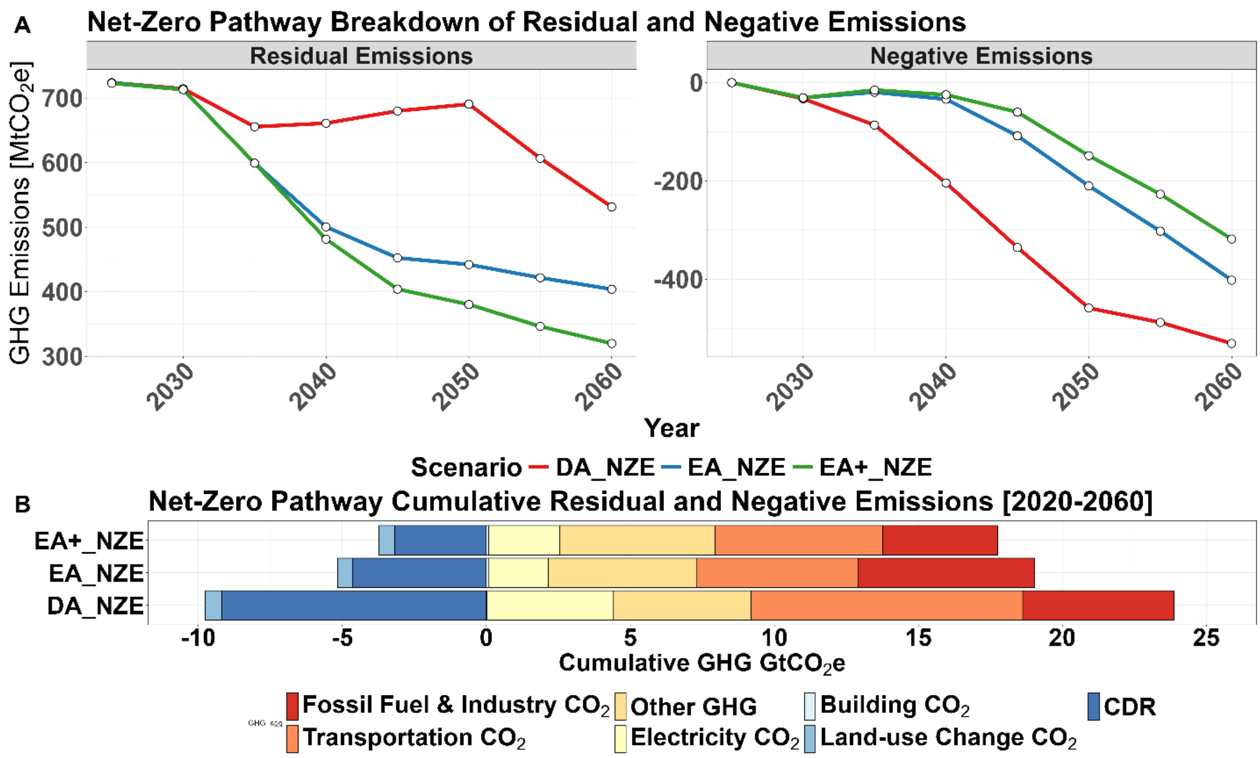
Source: Authors.

In the baseline scenario, the cumulative GHG emissions from the DA_Base scenario up to 2060 are projected to add up to 43.3 $GtCO_2e$. This cumulative emission represents the technological inertia within the energy system in the absence of significant energy transition policies in Saudi Arabia. Contrasting with this, the achievement of both near-term NDC targets and the long-term net-zero pathway implies that Saudi Arabia must limit its cumulative net emissions to approximately 14.1 $GtCO_2e$. Bridging the gap between the DA_Base scenario and the net-zero pathway demands substantial mitigation efforts. However, the early action (i.e., EA_Base) policy instruments are expected to decrease the cumulative emissions by 17.9% or 7.9 $GtCO_2e$ compared to the delayed action scenario. Conversely, the enhanced early action scenario (i.e., EA+_Base) is projected to achieve a more substantial reduction of about 31.1% compared to DA_Base and 16% compared to EA_Base. The advanced technology efforts in the EA_Base and EA+_Base scenarios result in a significant reduction of the mitigation gap by approximately 21.3 $GtCO_2e$ and 16.6 $GtCO_2e$, respectively. These early action policy scenarios hold substantial potential to reduce the inertia associated with the low-carbon technology transition, which can play a critical role in supporting Saudi Arabia's pursuit of its NDC and net-zero objectives.

3.3 Residual and Negative Emissions for NDC and Net Zero

This section aims to shed light on the sectoral emission reductions required to meet Saudi Arabia's NDC goal by 2030 and its ambitious shift towards achieving a net-zero economy by 2060. Figure 6a illustrates the key emission transformation required to accomplish Saudi Arabia's decarbonization objectives. It focuses on residual emissions and negative emission pathways within the three energy system scenario pathways. Figure 6b offers an overview of sector-specific cumulative residual emissions and carbon removal from 2025 to 2060.

Figure 6. (a) Residual and negative emissions trajectory; (b) Cumulative residual and negative emissions trajectory by sector.



Source: Authors.
Note: Carbon dioxide removal (CDR) in this graph represents direct air capture (DAC) with CCS technologies.

In the near term (2025-2030), which aligns with meeting the NDC target, the pathways for the three scenarios appear to overlap in both residual and negative emissions trajectories. During this period, the emissions constraint is less stringent, and the demand for negative emissions technology to offset residual emissions is thus low. As the net-zero decarbonization pathway commences in 2031, the delayed action (i.e., DA_NZE) scenario stands apart from the others due to its notably higher residual emissions. This divergence can be attributed to the pronounced technological inertia inherent in the DA_Base scenario, as discussed in section 3.2.2. To counterbalance the substantially higher residual emissions and align to achieve net-zero emissions, early deployment of carbon dioxide removal (CDR) is imperative.

Beyond 2035, a notable divergence becomes evident in the trajectory of residual emissions between EA_NZE and EA+_NZE. In comparison, the enhanced policy scenario (i.e., EA+_NZE) has a significantly higher potential to reduce residual emissions compared to EA_NZE. The reduction in residual emissions observed in the EA+_NZE scenario can be attributed to improvement in industrial efficiency and transportation. Primarily, enhancing industrial efficiency can be instrumental in reducing residual emissions, particularly in hard-to-abate sectors such as heavy industrial activities and transportation. As a result, the EA+_NZE scenario necessitates a less aggressive deployment of CDR solutions when compared to the EA_NZE scenario.

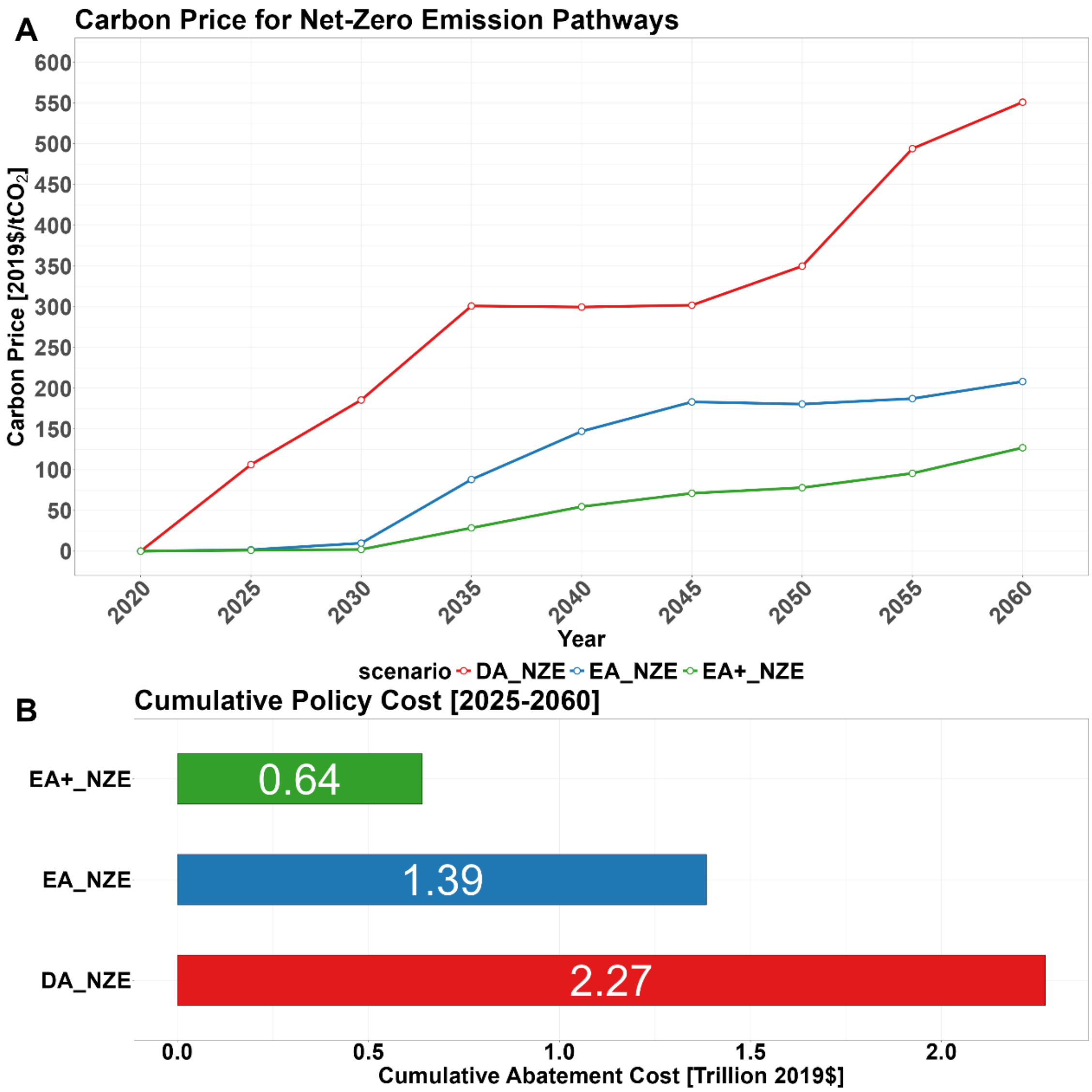
In the delayed action net-zero (DA_NZE) scenario, a cumulative negative emission of 9.8 GtCO2e is required to offset the residual emissions of 23.9 GtCO2e. The lower technological inertia associated with EA_NZE and EA+_NZE results in a notably lower cumulative demand for negative emissions compared to the DA_NZE scenario. These reductions amount to 50.3% and 61.4%, respectively. In the DA_NZE scenario, the transportation sector has the highest cumulative residual emissions due to slower technological advancements in transportation efficiency and electrification. In contrast, the EA_NZE and EA+_NZE scenarios, benefiting from more rapid technological progress in transportation, can potentially reduce cumulative residual emissions by approximately 40.8% and 38.7%, respectively.

Reaching Saudi Arabia's 2060 net-zero greenhouse gas emissions goal hinges on a significant reduction in emissions from its hydrocarbon-dependent industrial sector (Kamboj et al. 2023). The model's results suggest that to meet Saudi Arabia's net-zero target, the cumulative residual emissions from fossil fuel and industrial (FFI) activities range from 3.9 to 6.1 GtCO2. Although accomplishing deep decarbonization in the FFI sectors may pose challenges, the findings demonstrate that enhancing industrial energy efficiency can lead to a significant reduction in residual emissions, amounting to 32.4%.

3.4 Policy Cost Implications

Insights from the previous section highlighted that KSA's policy-driven strategies have the potential to steer emissions trajectories differently, as exemplified by the variations in residual and negative emission pathways. These findings shed light on the cost implications associated with the mitigation of GHG emissions.

Figure 7. (a) Carbon price for the policy scenarios; (b) Cumulative policy cost (2025-2060).



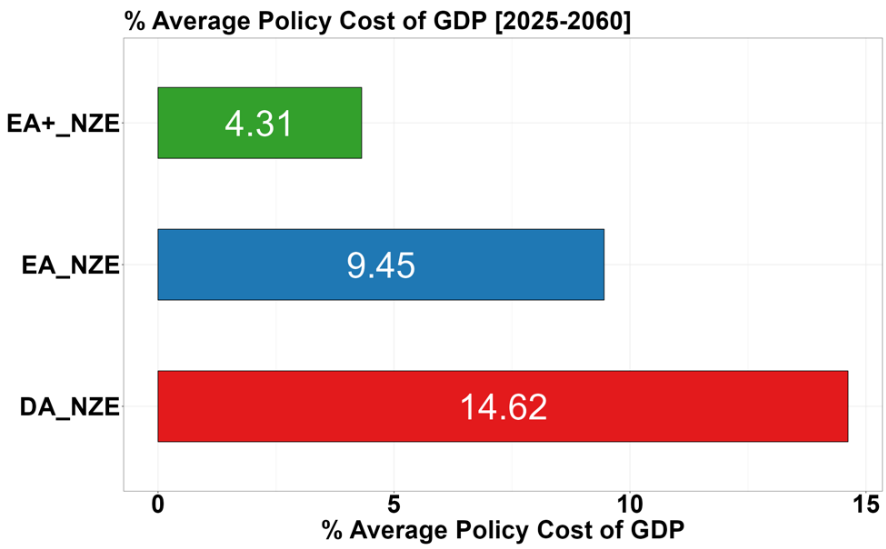
Source: Authors.
Note: Policy costs in Figure 7b are discounted at 5% from the year 2020.

Figure 7a presents the carbon price for each of the three scenarios across the mitigation periods. It is imperative to emphasize that the carbon prices showcased in Figure 7a are entirely independent and reflect diverse assumptions about Saudi Arabia's energy system discussed in section 2. The observed differences across the cost signify varying levels of cost-effectiveness associated with both sector-specific and economy-wide emissions reduction strategies. The delayed action scenario (DA_NZE) incurs the highest carbon price among all scenarios across all the time periods, primarily due to the scenario's elevated technological inertia associated with mitigating GHG emissions. However, the early action policy interventions induce a pivotal shift in the cost dynamics. As shown, the carbon price is lower for both EA_NZE and EA+_NZE compared to the DA_NZE scenario.

Figure 7b illustrates the cumulative policy cost for the scenario spanning from 2025 to 2060. Without the early energy-system policy actions, achieving long-term net-zero emissions in the DA_NZE scenario would require a total policy expenditure of about US$2.27 trillion. Nevertheless, the early action interventions in the form of current and planned policies are projected to reduce the cumulative policy costs to approximately US$1.39 trillion for the EA_NZE scenario, and even further to around US$0.64 trillion for the EA+_NZE scenario. This corresponds to a reduction of 38.8% compared to the DA_NZE scenario in the case of the EA_NZE scenario, and a substantial 71.8 reduction in the EA+_NZE scenario.

The significance of these cost reductions becomes apparent when assessed in the context of the average share of policy cost as a percentage of GDP from 2025 to 2060 (Figure 8). The comparison highlights that on average, the EA_NZE scenario can potentially reduce the economic burden by 5.14 percentage points per year compared to the DA_NZE scenario. Furthermore, for the EA+_NZE scenario, the deployment of advanced low-carbon technologies and strategies has the potential to cut the economic loss by a substantial 10.31 percentage points per year. The marginal abatement curves shown in Figure 1b (in the Appendix) further shed light on the cost-effectiveness associated with the respective scenarios. It is important to highlight that the annualized average policy cost, expressed as a percentage of GDP for the early actions scenario, falls within the range of cost estimates found in the net-zero emission literature. However, the estimate for delayed actions is an outlier, which is expected given that this scenario represents a future of minimal actions toward a low-carbon future.

Figure 8. Average annual policy cost expressed as a percentage of GDP (2025-2060).



Source: Authors.

4. Policy Implications and Conclusion

Saudi Arabia's ambitious aim to achieve net-zero GHG emissions across its economy by 2060 presents a complex challenge, primarily due to its substantial dependence on fossil fuel exports and significant domestic demand for fossil fuels. However, it also offers a unique opportunity to diversify the Kingdom's economy away from fossil fuels while promoting long-term economic resilience and sustainability. This study offers valuable insights into the feasibility of this ambitious goal by examining the associated mitigation policy costs for both current and proposed energy transition policies in Saudi Arabia. The findings reveal that these policies can make significant strides in lowering both emissions and primary energy consumption. Sustaining and amplifying the momentum of these policies into the future is crucial for reducing the low-carbon technological inertia associated with Saudi Arabia's net-zero ambitions. However, the analysis of the current trajectory of these energy transition policies reveals a potential shortfall in meeting the Nationally Determined Contributions (NDC) goals. Strengthening these policies and incorporating additional non-energy sector policies will be imperative to bridge and ensure that KSA can meet its emission reduction targets.

Insights from the study reveal that Saudi Arabia's comprehensive energy transition strategy collectively yields far-reaching outcomes compared to the impact of the policies in isolation. Moreover, the analysis of individual policy instruments reveals that non-industrial and industrial sectoral efficiency policies are the most effective policies in reducing Saudi Arabia's emissions. Enhancing energy efficiency presents many opportunities for the Kingdom's deep decarbonization aspiration. First, reducing energy demand improves the flexibility of decarbonizing hard-to-abate sectors. The results highlight the pivotal role that industrial energy efficiency can play in decarbonizing the country's economy. This is especially significant given the industrial sector is currently responsible for approximately 48% of the country's primary energy consumption. Furthermore, the results indicate that improving energy efficiency can also help mitigate the risks associated with the large-scale deployment of CDR technologies. These results illustrate the dual benefit of energy efficiency measures in Saudi Arabia's transition toward a lower-carbon future.

Saudi Arabia's path to net-zero emissions relies on a comprehensive strategy, including a 50% gas and 50% renewable capacity deployment in the power sector. The decarbonization of the power sector will not only contribute to emissions reductions in this sector but can also create substantial opportunities for decarbonization in pivotal end-use sectors, such as transportation and industry. Currently, decarbonizing Saudi Arabia's power and transport sectors would eliminate approximately 60% of the country's emissions. The study's results indicate that current electric vehicle targets and the expansion of public transportation will lead to modest emissions reductions in the short term. More ambitious and comprehensive measures will be required to fully harness the decarbonization potential of the transportation sector. In addition to electrification, future studies could explore the roles of alternative fuels such as hydrogen, biofuels, ammonia, and methanol in reducing emissions from heavy transportation modes like land freight, aviation, and shipping.

To achieve its net-zero target, Saudi Arabia will require further energy price rationalization using policy instruments that accurately reflect the true costs of different energy sources, including their environmental and social externality. This study reaffirms the critical role of Saudi Arabia's energy price reform in reducing primary energy consumption and GHG. Furthermore, implementing a carbon pricing mechanism can encourage businesses and individuals to invest in sustainable and low-carbon solutions while driving innovation in clean technologies. Although we do not model it explicitly, revenue generated from carbon pricing can be reinvested in renewable energy infrastructure, climate adaptation measures, and support for vulnerable communities affected by climate change.

Transitioning from a fossil-fuel-based economy to a carbon-neutral economy comes with significant cost implications. Importantly, this study reveals that Saudi Arabia's early actions, through current and planned energy transition policies, have the potential to significantly reduce the long-term financial burdens of transitioning to a net-zero economy. While these policies can lead to substantial reductions in long-term costs, it is important to emphasize that the relative costs associated with the energy transition policies remain substantial. One reason for the significant policy cost estimates is the study's limited scope, as it focuses solely on specific energy systems policies. Another contributing factor is the assumption that mitigation action occurs exclusively within the Kingdom, without the option to transfer carbon credits from other regions. While this analysis offers valuable insights into the challenges and opportunities of decarbonizing Saudi Arabia's economy, future studies could take a more comprehensive approach by considering a broader spectrum of cross-sectoral policies and the transfer of carbon credits. Such future research endeavors can complement this study by providing insights into how to efficiently allocate resources, thereby potentially minimizing the overall cost burden.

Endnotes

[1] Unlike the IMF (Clements et al. 2013), where each energy subsidy reform is defined to include multiple products that were reformed simultaneously, Overland et al. (2016) considered the reform of each product (e.g., gasoline, diesel, LPG, or kerosene) as a distinct episode. So, if four fuels were reformed simultaneously, the IMF would count it as a single episode, while Overland et al. (2016) would count it as four distinct episodes. In our database, we follow the same approach as the IMF in defining a single energy subsidy reform episode to include increases in the prices of multiple energy products that happen simultaneously (or that are staggered but separated by less than four weeks).

[2] The majority of episodes we found were separated by at least a month.

[3] An example of a commonly used search in Nexis combined these commands as follows: Different values of N were tested, with values between 5 and 10 providing an appropriate balance between relevance, precision, and manageability in the number of search results.

[4] The number of energy price reform episodes found for each country depends on the frequency of reform in that country. For example, in Saudi Arabia, gasoline prices had not changed in decades before the 2016 increase (Gasim and Matar 2022), while there have been many episodes in Nigeria over the same period (Akanle et al. 2014). It is also worth pointing out that countries and episodes receiving less coverage from news media published in English might be underrepresented in our database. Underrepresentation may also occur because certain countries have limited economic size or importance to global markets.

[5] We use the term deregulation to describe a country transitioning to an automatic pricing mechanism or market-based pricing.

[6] Selecting a policy instrument to achieve a certain policy objective generally depends on the cost-effectiveness of the instrument, its ease of implementation, and its political feasibility, among other factors. While energy price reform can be one of the most cost-effective policy instruments, it may also not be politically feasible, so some governments may be better off picking an alternative instrument. For example, if the government's objective is to improve the fiscal balance, one alternative policy could be raising income taxes for certain groups or introducing a low value-added tax. If the objective is to reduce emissions, a government may use regulatory instruments to achieve that goal instead of energy subsidy reform.

[7] TK.

[8] According to the World Bank's carbon pricing dashboard, there are currently only 39 national and subnational carbon taxes implemented worldwide (World Bank 2023c).

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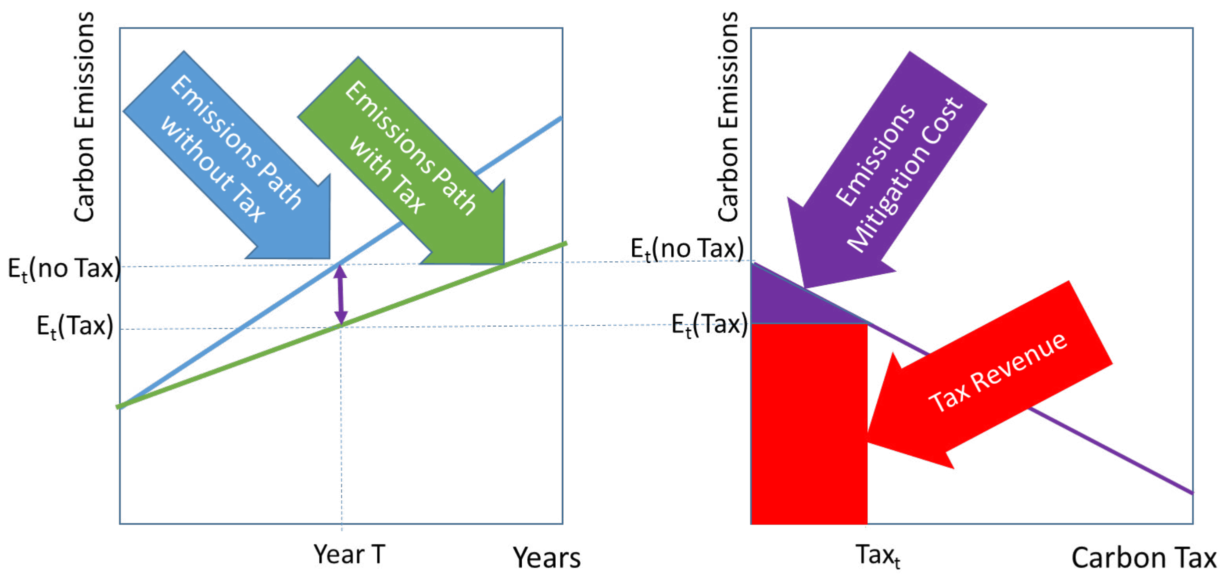
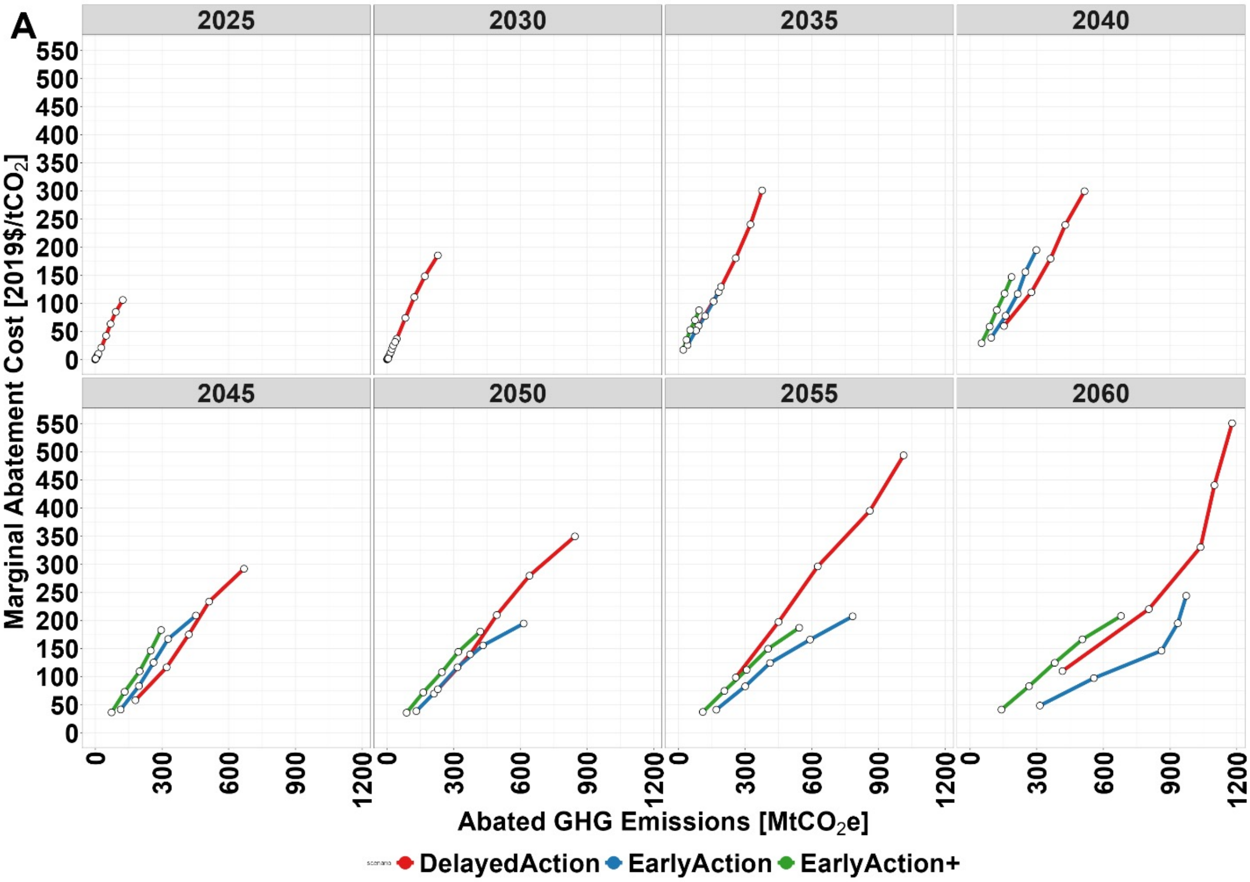
Appendix

Figure 1a. Schematic representation of emissions policy costs.



Source: Authors.

Figure 1b. Marginal abatement cost curve for the scenarios.



Source: Authors.

Table A1. Socioeconomic assumptions.

	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	Units
GDP	2.58	2.46	2.99	3.57	4.23	4.95	5.72	6.55	7.43	8.37	Trillion 2020 SAR
Population	31	35	39	43	46	50	53	56	58	60	Million

Source: Authors.

Table A2. Assumptions for energy efficiency improvements to key consumer sectors in the CurPol and CurPol+ scenarios.

			CAGR [2015-2030]			CAGR [2030-2060]		
Sector	End-use	Technology	CtFul	CurPol	CurPol+	CtFul	CurPol	CurPol+
Buildings	Residential	Cooling	0.29%	0.80%	0.80%	0.25%	0.76%	0.76%
	Commercial	Cooling	0.28%	0.80%	0.80%	0.25%	0.78%	0.78%
	Residential	Other	0.03%	0.49%	0.49%	0.03%	0.45%	0.45%
	Commercial	Other	0.03%	0.49%	0.49%	0.03%	0.45%	0.45%
Transportation	Four-wheelers	ICE	0.50%	1.60%	1.60%	0.50%	1.5%	1.5%
	Four-wheelers	Hybrid vehicles	0.50%	1.50%	1.50%	0.50%	1.4%	1.4%
	Four-wheelers	CNG	0.60%	1.60%	1.60%	0.60%	1.5%	1.5%
	Four-wheelers	BEV	0.50%	1.20%	1.20%	0.50%	1.1%	1.1%
	Four-wheelers	FCEV	0.60%	1.40%	1.40%	0.60%	1.3%	1.3%
Industry	Aggregated improvement		1.00%	1.00%	2.00%	1.00%	1.00%	2.00%

Source: Authors.

Table A3. Assumption of public transportation load factors for the CurPol+ scenario.

End-Use	Technology	2015	2030	2060
Bus	BEV/FCEV/hybrid liquids	15	15.6	19.5
Passenger train	NG/electric	200	200.8	260

Source: Authors.

Table A4. Assumption for non-energy costs for four-wheeler technologies.

Type	Technology	2015	2030	2060	Units
Car	BEV	13307	11065	10416	2020 USD
Car	FCEV	15290	12715	11365	2020 USD
Car	Hybrid vehicles	11038	11228	11849	2020 USD
Car	ICE	10468	10606	11480	2020 USD
Car	CNG	11588	11684	12569	2020 USD
Large car and truck	BEV	22476	20197	19203	2020 USD
Large car and truck	FCEV	25824	22502	19920	2020 USD
Large car and truck	Hybrid vehicles	20503	20249	20544	2020 USD
Large car and truck	ICE	19445	19127	19904	2020 USD
Large car and truck	CNG	21525	21071	21791	2020 USD
Mini car	BEV	6583	4283	4031	2020 USD
Mini car	FCEV	7938	5433	4180	2020 USD
Mini car	Hybrid vehicles	4579	4523	4588	2020 USD
Mini car	ICE	4343	4272	4445	2020 USD
Mini car	CNG	4808	4706	4867	2020 USD

Source: Authors.

Table A5. Overnight capital cost of electricity technologies for Saudi Arabia.

Technology	Parameter	Units	2020	2030	2060
Gas_CC	Capital	$/kW	1036	910	805
Gas_ST	Capital	$/kW	920	773	674
Gas_CCS	Capital	$/kW	2709	2061	1492
Liquids_CC	Capital	$/kW	1263	1263	1263
Liquids_ST	Capital	$/kW	1263	1263	1263
CSP	Capital	$/kW	6492	4333	3675
PV	Capital	$/kW	1331	750	556
Wind	Capital	$/kW	1459	948	671
Wind_offshore	Capital	$/kW	3620	2645	2117
Nuclear_Gen_III	Capital	$/kW	7427	6797	5446
Geothermal	Capital	$/kW	5794	5219	4418

Source: Authors.

Table A6. Fixed and variable operations and maintenance (O&M) costs of electricity technologies for Saudi Arabia.

Technology	Parameter	Units	2020	2030	2060
Gas_CC	Fixed	$/kW/year	28	28	28
	Variable	$/MWh	2	2	2
Gas_CCS	Fixed	$/kW/year	69	64	0
	Variable	$/MWh	6	6	0
Liquids_CC	Fixed	$/kW/year	21	21	21
	Variable	$/MWh	3	3	3
Liquids_ST	Fixed	$/kW/year	25	25	25
	Variable	$/MWh	3	3	3
Gas_ST	Fixed	$/kW/year	21	21	21
	Variable	$/MWh	5	5	5
CSP	Fixed	$/kW/year	66	57	56
	Variable	$/MWh	3	3	3
PV	Fixed	$/kW/year	23	15	12
	Variable	$/MWh	0	0	0
Wind	Fixed	$/kW/year	43	39	30
	Variable	$/MWh	0	0	0
Wind_offshore	Fixed	$/kW/year	111	86	65
	Variable	$/MWh	0	0	0
Nuclear_Gen_III	Fixed	$/kW/year	146	146	146
	Variable	$/MWh	3	3	3
Geothermal	Fixed	$/kW/year	200	200	200
		$/MWh	0	0	0

Source: Authors.

Table A7. Capacity factors and lifetime of electricity technologies in Saudi Arabia.

Technology	Capacity factor	Lifetime
Gas_CC	0.8	35
Gas_ST	0.8	20
Gas_CCS	0.8	35
Liquids_CC	0.8	20
Liquids_ST	0.8	20
CSP	0.3	30
PV	0.25	25
Wind	0.3	25
Wind_offshore	0.4	25
Nuclear_Gen_III	0.9	50
Geothermal	0.9	30

Source: Authors.

Notes

About the Authors

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Raphael is Lead researcher in the Climate and Sustainability program. Raphael Apeaning is an integrated assessment modeler with expertise in energy transition strategies and policy. Prior to joining KAPSARC, he was a researcher at the Institute for Responsible Carbon Removal in Washington, DC, where he played a key role in expanding the portfolio of carbon dioxide removal technologies for climate modeling and developing market mechanisms for negative emission technologies.

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About the Project

This study is a part of the Climate Adaptation and Mitigation Partnership (CAMP) project.

The CAMP project is timely and crucial for Saudi Arabia given the mounting risks associated with climate change impacts, the urgency of pushing toward a low-carbon future while maintaining economic growth nationally, and the potential economic ramifications of global mitigation efforts on the Saudi energy sector and economy. Against this backdrop, the CAMP project investigates (1) the climate conditions in Saudi Arabia, (2) the sectoral impacts and the role of adaptation measures, and (3) the pathways of the Saudi economy to achieve a low-carbon future or climate neutrality by the mid-century. (4) The study will also adopt the circular carbon economy concept in characterizing the Saudi government's efforts to decarbonize its own economy while meeting its growth aspirations.

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