



# Energy Trilemma and the hydrocarbon industry - the Indian scenario

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## Abstract

The energy trilemma presents a formidable challenge, but it also offers an opportunity for the hydrocarbon industry to evolve and play a role in a cleaner, more sustainable energy future. While the transition away from hydrocarbons is necessary to combat climate change, the industry can leverage its expertise and resources to contribute to the development of cleaner energy technologies and solutions. By embracing diversification, technological advancement, and global collaboration, the hydrocarbon industry can navigate the complexities of the energy trilemma and secure its place in the energy landscape of tomorrow. India's approach to managing the energy trilemma is a complex and dynamic process. By pursuing energy security through diversification, ensuring energy equity through electrification and clean cooking solutions, and prioritizing environmental sustainability through renewable energy and conservation efforts, India is taking significant strides toward a more sustainable energy future. While challenges remain, such as financing and infrastructure development, India's commitment to addressing the energy trilemma demonstrates its dedication to a cleaner, more equitable, and secure energy landscape. As India continues to implement these strategies, it serves as an inspiring model for other nations striving to strike the delicate balance of the energy trilemma in the 21st century.

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*Keywords: Energy Trilemma, hydrocarbon industry, green energy*

## Introduction

As the world populace continues to increase exponentially and becomes more urbanised and more affluent, the demand for power, heat and transport will rise manifold with it. The global energy demand is expected to increase just as fast and potentially double by 2050 (IEA, 2020a). To keep pace with the global energy mandate, the estimated investment on energy infrastructure between now and 2050 is nearly US\$50 trillion (ETC, 2020). Given the critical nature of energy supply and the substantial financial commitment, the effective resource allocation is of utmost importance. The world's energy landscape is experiencing a profound transformation, primarily motivated by the urgent need to address the Energy Trilemma: *reducing greenhouse gas emissions, ensuring energy security, and promoting economic growth*. Approximately 90% of the world has adopted net-zero emission targets, such as 'Net Zero 2021', with existing technologies capable of achieving significant emissions reductions by 2030 (IEA, 2020b).

However, transitioning to low-carbon and renewable energy sources demands substantial capital and government support, leading to trade-offs with affordability. Balancing these investments in renewables could result in higher energy prices. Energy security requires sufficient power capacity to meet demand while ensuring energy availability and network stability. This often entails a choice between affordable conventional power sources and more expensive yet sustainable renewable energy. Countries with inadequate energy infrastructure and limited natural resources may be compelled to import costly energy sources, jeopardizing affordability.

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Importing more affordable sources may conflict with sustainability aspirations. These examples underscore the inherent trade-offs within the Energy Trilemma, emphasizing the need for a holistic and integrated approach that considers security, sustainability, and affordability simultaneously.

In this context, the hydrocarbon industry, historically dominant in the energy sector, faces both challenges and opportunities in providing affordable, sustainable, and secure energy sources. As one of the world's fastest-growing economies, India faces a distinctive array of challenges and opportunities as it tackles the Energy Trilemma. The nation's decisions in meeting the energy needs of its 1.4 billion people will profoundly shape its energy future. This article delves into the distinctive position of the hydrocarbon industry within the context of the Energy Trilemma, particularly in India.

## Understanding Energy Trilemma

Three challenges must be addressed when dealing with energy investment and demand, and these challenges involve trade-offs when prioritizing one over the other two. These challenges collectively form what is known as the Energy Trilemma (Figure 1):

- *Energy security*
- *Energy sustainability*
- *Energy affordability*

Visualize the trilemma as three distinct axes, each with its own scoring or weighting system. A favourable score corresponds to a higher position along a particular axis. None of these axes inherently outweighs the others, so the ideal scenario is to achieve high scores on all three. However, the challenge lies in making this achievement feasible. The significance of the Energy Trilemma lies in its capacity to effectively convey the relative positioning concerning all three aspects.

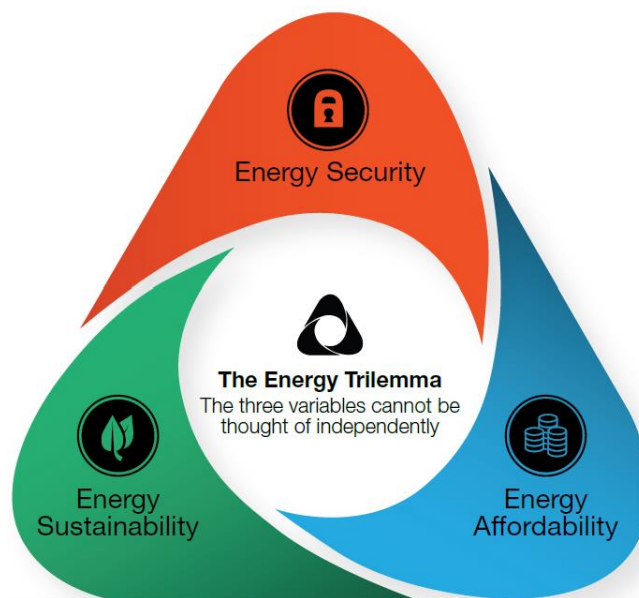


Figure 1: Three dependent variables of energy Trilemma (Arup, 2023).

### *a. Ensuring energy security*

Energy security encompasses the assurance of a consistent and uninterrupted energy supply. For decades, hydrocarbons have served as a pivotal solution in meeting the world's energy needs, offering a dependable energy source for transportation, electricity generation, and industrial applications. The hydrocarbon industry has established a robust infrastructure that ensures the accessibility of energy resources. Nevertheless, geopolitical conflicts, disruptions in supply chains, and fluctuations in prices and environmental concerns have shed light on the vulnerabilities associated with this heavy reliance on hydrocarbons. Consequently, diversifying energy sources and enhancing energy efficiency emerge as critical strategies to fortify energy security.

### *b. Reducing greenhouse gas emissions*

The need to confront climate change has gained heightened recognition in recent times. To improve its impacts, there is a progressively widespread agreement that we must diminish our dependence on fossil fuels, including hydrocarbons such as oil and natural gas. The hydrocarbon industry significantly contributes to greenhouse gas emissions, primarily through the combustion of these fossil fuels. Consequently, making the transition to cleaner energy sources is imperative to fulfil emission reduction objectives and address the challenge of climate change effectively.

### *c. Promoting economic growth*

The hydrocarbon industry has historically served as a fundamental driver of economic expansion and progress in many countries. It not only creates employment opportunities, bolsters interconnected sectors, but also plays a substantial role in government revenue generation. Nevertheless, the economic viability of the hydrocarbon industry confronts obstacles, particularly in light of the global shift towards cleaner energy alternatives. In response, the industry must adjust to evolving market dynamics and explore fresh avenues for growth within a low-carbon future.

## **Energy Trilemma and hydrocarbon industry**

The energy trilemma presents a complex set of challenges for the hydrocarbon industry, but it also offers opportunities for innovation and transformation. Here are several key considerations for the industry's future:

### ➤ *Diversification and decarbonization*

To address the climate imperative, the hydrocarbon industry must diversify its portfolio by investing in cleaner technologies such as carbon capture and storage (CCS), hydrogen production, and renewable energy. Many oil and gas companies are already taking steps to reduce their carbon footprint and explore low-carbon business models (IEA, 2020c). These efforts can help the industry remain relevant in a carbon-constrained world.

### ➤ *Technological advancements*

Continued innovation in hydrocarbon extraction and processing technologies can improve efficiency and reduce environmental impacts. Enhanced oil recovery techniques, advanced drilling methods, and cleaner refining processes can contribute to a more sustainable hydrocarbon industry.

➤ *Transition to energy companies*

Some oil and gas companies are rebranding themselves as "energy companies" rather than focusing solely on hydrocarbons. They are investing in renewable energy projects, electric vehicle infrastructure, and energy storage solutions (Liebreich, 2023). This strategic shift allows these companies to participate in the growing clean energy sector while leveraging their existing expertise and infrastructure.

➤ *Global collaboration*

Addressing the energy trilemma requires global cooperation. Governments, industry stakeholders, and international organizations must work together to set clear policy frameworks, provide incentives for clean energy investments, and facilitate the transition to a more sustainable energy system (IEA, 2020d).

## **India's strategy for managing energy trilemma**

India possesses significant potential for harnessing renewable energy, particularly through solar and wind resources (Kapadia et al., 2019). The government has set ambitious targets for renewable energy, with plans to install 175 GW of renewable capacity by 2022 and a staggering 450 GW by 2030 (Jain, 2023). Investments in initiatives such as solar parks, wind farms, and green hydrogen projects hold the potential to not only reduce emissions but also stimulate job creation and foster economic growth. To expedite its journey toward achieving Net Zero emissions, India must implement novel policies like carbon pricing and leverage groundbreaking technologies such as Carbon Capture Utilisation and Storage (CCUS). Additionally, accelerating the transition to electric mobility and promoting the production of green steel are essential steps. The adoption of CCUS within the industrial and energy sectors represents a substantial commitment in India's pursuit of Net Zero emissions (NITI Aayog, 2022). It's worth noting that India's historical contribution to global greenhouse gas emissions from 1850 to 2021 amounted to less than 4 percent which is less than half the global average (NITI Aayog, 2023).

India's path to achieving Net Zero emissions can be envisioned through two distinct scenarios. The first scenario, referred to as the *Line of Sight (LoS) Scenario*, entails the execution of India's Nationally Determined Contributions (NDCs) and the utilization of existing policies (Gupta et al., 2022). This scenario also aligns with technological advancements within the current trajectory and encompasses a shift in demand towards sustainable alternatives, exemplified by the widespread adoption of electric vehicles in specific regions.

On the other hand, the second scenario, known as the *Accelerated Scenario*, envisages the adoption of innovative policies like carbon pricing and the swift deployment of breakthrough technologies such as CCUS (Ahmad, 2023). This scenario places a strong emphasis on expediting the implementation of existing strategies and a rapid transition towards sustainable consumption practices. This includes the widespread adoption of electric vehicles, alternative materials, coarse cereals, and the production of green steel.

It is undeniable that coal, oil, and gas contribute to more than 80 percent of greenhouse gas emissions and simulation studies reveal that the climate change is rising faster now (UN, 2023). To effectively propel a successful low-carbon energy transition, the convergence of thoughtfully chosen strategies can yield substantial outcomes. These strategies encompass a range of actions, including augmenting the proportion of renewable energy in electricity generation, implementing CCUS technologies in fossil or biomass power plants, incorporating hydrogen and methanol in both the energy and transportation sectors, advocating for the use

of green hydrogen within steel, refinery, and chemical industries, while also making affordable blue hydrogen accessible, and tapping into the potential of Small Modular Reactors (SMRs) for nuclear power generation.

The success of these strategies hinges on various pivotal factors, which encompass access to ample financial resources, collaborative efforts in technology advancement, and the implementation of comprehensive policies such as carbon pricing and taxation. Financial measures that encourage the adoption of alternative resources while discouraging the use of fossil fuels will be pivotal in propelling this transition forward. Furthermore, cooperative research and development initiatives, international partnerships, and agreements for technology transfer are imperative for bolstering technological expertise and broadening the workforce.

Nations possessing well-established renewable energy markets can assume a central role by imparting their knowledge and perspectives regarding the surmounting of hurdles in deployment, including financial and regulatory obstacles. By uniting in concerted endeavours, we can pave the way for the emergence of fresh markets for sustainable energy technologies, nurturing the evolution of inventive business and economic frameworks. This endeavour encompasses harnessing financing tools such as green bonds or public-private collaborations and delving into advanced materials like electrolysers, catalysts, and rare earth elements. The overarching objective should be to strike a balance in the energy trilemma, encompassing energy security, energy equity, and environmental sustainability.

## **Energy security**

Energy security is paramount for any nation's economic stability and growth. India's strategy for energy security revolves around diversifying its energy sources and reducing its dependence on fossil fuels, particularly oil. Here's how India is achieving this:

*a. Promoting renewable energy:* India has recognized the importance of renewable energy sources like solar and wind. The country has set ambitious targets to increase its renewable energy capacity, aiming to install 450 GW of renewable power by 2030 (Jain, 2023). This move not only enhances energy security but also reduces greenhouse gas emissions.

*b. Nuclear energy:* India is also investing in nuclear energy as a clean and reliable source of power. The country is expanding its nuclear energy capacity while ensuring safety and security.

*c. Energy efficiency:* Improving energy efficiency is a key pillar of India's energy security strategy. Initiatives like the Perform, Achieve, and Trade (PAT) scheme have been instrumental in reducing energy consumption in industries.

## **Energy equity**

Energy equity entails ensuring that all segments of society have access to affordable and reliable energy. India has taken significant steps to bridge the energy access gap and promote equity:

*a. Rural electrification:* The Saubhagya scheme, launched in 2017 (PIB, 2021), aims to provide electricity connections to all rural households. By electrifying remote areas, India is improving the quality of life for millions and promoting economic development.

*b. Clean cooking solutions:* India is promoting clean cooking solutions to reduce the health and environmental impacts of traditional biomass cooking. Initiatives like the Pradhan Mantri Ujjwala Yojana (Shah, 2022) have provided LPG connections to millions of households.

*c. Energy subsidy reform:* India is gradually reforming its energy subsidies to target those in need while reducing the fiscal burden. This ensures that energy subsidies are directed to those who require them most.

## Environmental sustainability

Environmental sustainability is a global imperative, and India is taking substantial measures to reduce its carbon footprint as listed below.

*a. Renewable energy transition:* By promoting solar and wind power, India is significantly reducing its reliance on coal and other fossil fuels, thus lowering carbon emissions.

*b. Afforestation and reforestation:* India has launched initiatives like the Green India Mission (PIB, 2022) to increase forest and tree cover, aiding in carbon sequestration and biodiversity conservation.

*c. Electric mobility:* Encouraging the adoption of electric vehicles (EVs) is a cornerstone of India's environmental sustainability strategy. Incentives for EVs and charging infrastructure development are supporting this transition.

## Conclusions

The Energy Trilemma presents a multifaceted challenge for the hydrocarbon industry, but it also offers opportunities for transformation and growth. By embracing cleaner technologies, diversifying into renewable energy, and addressing emissions, the hydrocarbon industry can contribute to a more sustainable energy future. Success will require innovation, collaboration, and a clear commitment to balancing the three dimensions of the Energy Trilemma, ensuring a secure, sustainable, and economically viable energy supply for generations to come. Balancing the Energy Trilemma in India is a complex but imperative endeavour. The nation's commitment to addressing greenhouse gas emissions, ensuring energy security, and promoting economic growth is crucial for a sustainable and prosperous future. By embracing renewable energy, enhancing energy efficiency, and investing in domestic production, India can navigate this trilemma successfully, setting an example for sustainable development and energy transition on a global scale. Achieving this balance will not only secure India's energy future but also contribute to a healthier planet and improved quality of life for its citizens.

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*Sand dunes in Nubra Valley, Ladakh, India. Nubra Valley is a cold desert in Ladakh Himalaya, where the formation of sand dunes is controlled by lithology and geomorphic agents involving fluvial, glacial and aeolian processes, with the role of aeolian processes predominating compared with others. (Photo courtesy: Ritesh M. Joshi)*