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RE-VISITING THE ROADMAPS TO LOW CARBON ECONOMY

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Abstract

While there is a growing demand for energy to sustain economic development, fossil fuels remain a threat to climate change. Yet, among all fossil fuels—natural gas has low-carbon composition—which is crucial to achieving both energy security and decarbonized economic development. Here, we present the roadmaps to low-carbon economy and provide conceptual tools to navigate the paradigm of clean energy transition.

Keywords: natural gas; low-carbon economy; fossil fuel; energy consumption; green growth

1.0 Introduction

1.1 History of natural gas

Natural gas is colorless in nature but highly flammable gaseous hydrocarbon consisting of methane and ethane, hence, can be termed methane gas. It is a form of fossil fuel used for electricity generation, heating, cooking, and fueling certain vehicles. Its first discovery centuries ago is linked to Iran, where Ancient Persian fire-worshippers are believed to ignite the gas for their worship (Solomon, 2022). In ancient Greece, the popular Oracle at Delphi in mount Parnassus has a temple built on a site where natural gas seeps caused flames. The Chinese made drinkable water from seawater by boiling seawater using natural gas transported by crude pipelines made from bamboo. Though natural gas has been in existence since ancient times, commercial use became recent. The British were the first to commercialize natural gas in 1785 when various households and streets were light up from the burning of coal using natural gas. The native Americans were also the first in the United States to discover the properties of natural gas by igniting the gases which flow into and around Lake Erie. Explorers in France also witnessed these practices in 1626 (Natgas, 2022).

1.2 Production and distribution of natural gas

Two forms of natural gas generation (i.e., conventional and unconventional) exist based on the location of reserves. Conventional natural gas is obtained via the simplest formation—where the gas produced during the process of natural gas formation migrates through pores in a permeable rock until it gets trapped in an impermeable caprock. Conventional natural gas deposits are mostly found with oil deposits and are relatively easy to access, which in such cases is termed associated gas (CSIRO, 2020; IGU, 2020). Associated gas contains some light liquids such as propane, butane, ethane, and natural gasoline and thus can be referred to as wet gas. Conventional natural gas is extracted using an original drilling method called vertical well drilling, pumping, and compression techniques. When natural gas comes from reservoirs that contain gas without oil (natural gas wells), it is called non-associated. Such gas can be described as dry gas (Solomon, 2022).

In the case of unconventional natural gas, the deposits are much more difficult to access because they are located beneath the earth's surface. This type of gas deposit is found trapped in dense rock formations classified as impenetrable. Unconventional natural gas is commonly extracted from coalbed methane, methane hydrates, shale gas, and tight gas sandstone (IGU, 2020; JustEnergy, 2021).

For natural gas to be made available for end-users, it gets extracted from the earth and undergoes purification processing. This is a complex process that involves high-level engineering and technical know-how.

1.3 Importance of natural gas

Natural gas is considered the cleanest (low-carbon) fossil fuel in the world. Its combustion does not produce ash residues, sulfur oxides, and only negligible nitrogen, thus making it stand out from other fossil fuels (JustEnergy, 2021). There is a release of a substantial amount of energy when natural gas is burnt, making it a very useful source of energy with several benefits, hence, observing a steady growth in production and consumption. In the last two decades, global natural gas utilization has increased by 23% of the total global energy demand (IEA, 2020).

Natural gas is essential for electric power plants, industrial use, residential use commercial use, and transportation. Natural gas is used to power electric power plants. It has become important in the electric power sector to generate electricity. For instance, the electric power sector accounted for about 38% of total U.S. natural gas utilization in 2020 and contributes about 33% of the U.S. electric power sector's primary energy consumption (EIA, 2021; Hobart, 2022; JustEnergy, 2021). The industrial use of natural gas in the US accounts for about a third of all-natural gas use. It serves as a source of heat to keep factories warm and for incineration. It equally serves as an important source of heat in the manufacturing process of glass paper, ceramics, tile, bricks, steel, and cement. Natural gas also serves as feedstock in making products like antifreeze, fabrics, fertilizer, pharmaceutical plastics, and other chemicals namely acetic acid, methanol, and propane (EIA, 2021; JustEnergy, 2021). Residential use of natural gas goes into cooking, heating, doing laundry, powering electrical appliances, among others. Commercial use of natural gas entails heating buildings and water, refrigeration and cooling systems, providing outdoor lighting, and powering equipment (EIA, 2021; Hobart, 2022). Gas as a vehicle fuel is available as compressed natural gas (CNG) and liquefied natural gas (LNG). It can be used for cars, vans, buses, and trucks, with many different models on the market today from established manufacturers. LNG is also becoming the fuel of choice for the shipping industry due to its low sulfur emissions. The natural gas vehicle coalition estimates about 120,000 Natural Gas Vehicles (NGV) in the US and more than 8.7 million NGV worldwide (NGVA, 2019).

2.0 Energy consumption

The rise in energy consumption over the past decades can be attributed to increasing population and standard of living, hence, current energy planning is highly dependent on fossil fuels, raising concerns about environmental pollution. These concerns have triggered global action to combat GHG emissions by transitioning to sustainable and clean energy (Ayodele *et al.*, 2021; Owusu *et al.*, 2016; Sarkodie *et al.*, 2021).

Renewable energy can be defined as energy flows obtained by natural processes. It comes from sources that are continuously and naturally replenished. This process takes place over a relatively short period. Renewable energy emanates from geophysical processes such as wind, falling water, sunlight, sustainable biomass, and tides (Coburn *et al.*, 2004). The main forms of renewable energy sources include solar, wind, tidal, geothermal, hydropower, and biomass. The production and consumption of renewable energy play a vital role in the transition toward a climate-neutral economy (Sarkodie *et al.*, 2018). Renewables outpace conventional energy sources, contributing to the decarbonization needed to counter climate change. The significance of this sector is proven by the increasing share of renewables in the global energy market (Arcelay *et al.*, 2021).

Renewable energy contributed about 10.9% of global energy requirements in 2002, with a projected increase of 1.5% per annum (Hersh, 2006). Renewable technologies contributed around 11% of global primary energy in 2019 (Ritchie *et al.*, 2020). The share of renewables in global electricity generation in 2020 jumped to 29%, up from 27% in 2019 (IEA, 2020). The EU's share of total final energy consumption from renewable resources stood at 22.1 % in 2020, which is around 2% above its 20% target compared to 9.6% in 2014. The share of renewable energy used in transport activities in the EU reached 10.2% in 2020 (Eurostat, 2022).

Non-renewable energy is described as unsustainable energy sources derived from the earth while existing in limited quantities. Non-renewable energy includes fossil fuels in existence are coal, oil, natural gas, coal products, derived gas, crude oil, and petroleum products, as well as, nuclear energy (Hossain, 2012). Fossil fuels refer to energy stocks that cannot be replenished and have finite available quantities found in nature, viz. hydrocarbons formed from organic matter (Hersh, 2006). Non-renewable energy accounted for 85.9 % of the total primary energy in 2014 (Nadimi *et al.*, 2017). Non-renewable sources are not environmentally friendly and can have serious effects on health outcomes. Coal ranks as the worst among fossil fuels with regards to CO_2 emitted per unit of energy generated. Coal contributes 20-30% of the total energy in industrialized countries. Petroleum emits sulfur and carbon monoxide which can cause acid rain (Alrikabi, 2014).

2.1 Natural gas as a sustainable fossil fuel

Though natural gas is one of the sustainable forms of fossil fuel, its future is yet unclear in terms of decarbonized energy systems. Natural gas could play the role of bridging fuel during a transition phase, serve as the main backup for renewable power generation, or could be steadily phased out and substituted by alternative energy sources (Holz *et al.*, 2016), Howarth (2014) in contrast revealed that though natural gas is believed to emit low greenhouse gas emissions than coal and oil, but highly composed of methane and extremely potent of greenhouse gas. Several nations are instituting measures to combat climate change because it is becoming a driving force for economic growth. Natural gas is also competing strongly with other fossil fuels from an efficiency and emission perspective as the fuel of choice for power generation, though it has price volatility and supply-chain security concerns. Some power generation still favors coal and nuclear in its power generation portfolio, though natural gas is rapidly increasing its market share and demand. Nations are therefore urged to take the necessary steps in cutting down GHG emissions to protect the environment which is increasingly being used as a tool for measuring economic growth. United Arab Emirates was one of the nations in 2006 to address its economic and environmental challenges of the 21st

century by allocating substantial financial investment for broad-based initiatives to make Masdar city a sustainable city (Nader, 2009).

2.2 Decarbonization: Merging drawbacks & energy-climate goals

Global climate change and energy security have widespread political, societal, and economic impacts. The lack of energy security can increase the exposure to geopolitical tensions and undermine economic development. The policy for addressing the climate change and energy security problems set off numerous security challenges including forced migration, water shortage, decrease in harvest, and dynamic political conflict (Ladislaw *et al.*, 2008). The formulated policy should avoid disrupting the existing energy security coupled with the avoidance of climate change security. Both climate change and energy security problems will evolve over the horizon—with continuous emergence in scientific and technical knowledge, economic and political circumstances. Policy and decision-making processes will be affected by these developments of consistent change in climate sciences. Nevertheless, broader and cohesive policies are key to addressing both problems effectively.

Scientific understanding of climate change and the impact of the changes and the effective process of mitigating the problems is continuously evolving over the past decades. Although the available scientific knowledge is inadequate and cannot provide the accurate prediction that policymakers may desire—which may provide probable estimates of GHG emissions to a certain degree of confidence. Policymakers should formulate flexible policies that can easily adjust based on urgent action resulting from evolving scientific understanding of climate systems. The policies should acknowledge that some level of climate change is already happening in respective to mitigation policies. For instance, the rapid rise in sea level, high rate of ice melting, and decrease in water supply threaten major ecosystems to adapt to the current changes (NationalGeographic, 2021; TheGuardian, 2021; UNCC, 2020).

The attitude towards climate change and energy security may change over time depending on the public concern, perceived cost, and spill-over effect of policy implementation. The general public is usually concerned about energy security during high market prices, price volatility, scarce resource competition, and vulnerable infrastructure (Ladislaw *et al.*, 2008). Awareness of climate change increases after experiencing extreme weather events and alarming rates of GHG emissions. The decarbonization of energy supplies is not an easy task as policymakers are required to formulate and implement appropriate policies in tandem with different political views on climate change and energy security. For example, there may be significant political activism for renewable energy sources and carbon abatement programs if the public is threatened by climate events (Fisher *et al.*, 2021). However, the rise in isolationism among the public may hamper international cooperation on climate change and energy security solutions (Torpman, 2021). Another scenario is where the public is more concerned about energy security by preserving the brown economy than the green economy, viz. decarbonizing policies to decline climate change. Policies to bring forth may prioritize low cost, stability, adequate support for domestic but positively at the expense of clean energy, and thus undermining the support for climate change mitigating policies. Alternatively, alarming concerns about climate change than energy security may result in strong public and political support for mitigating and adaptation policies whiles prioritizing less on energy security mostly overlap with a period of stable and low fossil fuel price, affecting the deployment of expensive clean energy technologies (OECD, 2007). Citizens may express less concern about climate change and energy security, which may hamper the development of renewable energy and technologies (ESS, 2018).

The pathway in transforming the global energy sector from fossil-based to zero-carbon future is termed as energy transition (IRENA, 2022). Because there is a need to reduce energy-related CO_2 emissions to limit climate change, there has been a call for immediate action to decarbonize the global energy sector. Though global energy transition is underway, further action is required to reduce carbon emissions and mitigate its effect on climate change. The transition of the energy sector to a low carbon future should not be limited to only energy technologies or infrastructure but also to institutions and organizations which govern these processes (Milchram *et al.*, 2019). Both developed and developing countries are trying to accelerate the increasing demand for power by bridging the gap between demand and supply for economic and social growth (Sarkodie *et al.*, 2020). Renewable energy is the best bet in the transition process to tackle power shortages and environmental degradation throughout the transition process. Several research report phasing out fossil fuels completely will affect the energy supply, hence, recommending a progressive pathway for repealing fossil fuels or replacing them with natural gas which is a more sustainable form of fossil fuel. Child *et al.* (2018) reviewed energy transition scenarios and highlighted the neglect of biochemical, biodiversity, and climate change effects on emission reduction. These concerns have been recently addressed and can be linked with sustainability guardrail as well as planetary boundaries which serve as guilds to a sustainable future.

3.0 Energy security and climate change trade-offs

Energy supply security plays a crucial role in global energy policy and environmental sustainability. There is a convergence between climate change and energy security—as development and improvement of energy efficiency trickle down to a reduction in energy demand creating a “win-win situation”. The rise in energy efficiency has the potential to reduce carbon emissions generated by economic activities via the reduction in energy utilization. For instance, energy efficiency measures are estimated to decline carbon emissions by 40% in the US by 2030 (McKinsey, 2009). The climate change approach that seeks to replace higher emission carbon fuel with lower emission fuel sources like natural gas can trigger energy security problems. For instance, replacing coal combusting with natural gas in the plant will effectively reduce carbon emissions. This may increase the number of regions that rely on the importation of national gas. Similarly, as Russia supplies Europe with natural gas, any supply interruption will put Europe at risk.

Chester (2010) explained that energy security has unimpeded access or no planned sources of energy—by not relying on limited energy sources or tied to a particular geographic region for its sources of energy—but an abundant energy resource and energy supply which can withstand external shocks. Other authors seem to have a different stand on the definition of energy security because of the agreement that security has to do with risks (Winzer, 2012).

Stringer (2008) also defines energy security as an umbrella term that is used to connect energy, economic growth, and political power. Though energy security does not have a definite definition, various definitions from the author affirm the same theme for energy security which is energy availability, infrastructure, energy prices, societal effects, environment, governance, and energy efficiency. Energy security needs to be maintained during a transition period. This requires energy systems to deal with the continuity shocks and long-term stress, and its flexibility for energy systems and supply chain to return to the original state after a global disruption. It is however unclear how an effective or alternative supply chain, such as renewable energy technologies will provide energy security in a transition period. Hoggett (2014) believes other fossil fuel supply chains have the tenacity to be quite resilient except for oil and gas which cannot stand external shocks. Most developed countries are tackling the climate change importance to decarbonization and its affordability to energy security.

The scale of trade-off is significantly influenced by the economic condition. Price increase causes a decrease in demand, which may positively impact energy security and climate change. However, the rise in the price of fuel may drive demand for the fuel substitute that could put the security and climate goals in conflict thereby affecting energy security (Ladislaw *et al.*, 2008). The choice of the best policy will usually be complex, but the skill and understanding to navigate the transition to create a green energy mix will only be feasible with a clear focus on the preferred choice and its implication.

4.0 Technological change for low carbon future

Though tackling climate change is linked with various uncertainties in its management of global warming, it will require deploying and developing low-carbon technologies to combat climate change. The role of existing and new technologies undeniably plays an important role in tackling the challenges of both climate change and energy security. Breakthrough technological innovations will be required to revolutionize the transportation, energy production, and utilization sectors—such as renewable, sequestration, and carbon capture technologies. Other technological innovations are still in development and may take decades to be commercialized, by which society may have exceeded the point of no return in terms of GHG emissions (Ladislaw et al., 2008). It will therefore be risky to construct policies that are centered on technological breakthroughs since it is impossible to predict its availability in the foreseeable future. On the other hand, an unexpected technological breakthrough may be achieved to revolutionize an entire industry. Thus, adopting flexible policies to easily incorporate such technologies will be required.

The need for reallocation of investment for R&D in the energy sector should be a priority to combat emissions by making low-carbon options competitive as well as introducing new technologies given the fact that the current energy sector relies largely on fossil fuel consumption though it has a low capital turnover. There are no definite solutions to solving the climate change problem in relation to its socio-economic analysis of mitigation, though various broad portfolios of subsidizing technologies will need to be put in place. Additionally, various significant research and innovation need to be put in place to deal with the mitigation process in the long run (Tavoni *et al.*, 2012). There is a key characteristic of energy technology that is the focal point during the mitigation process that could play a role in bridging uncertainty that exists while showing resilience, flexibility, and adaptability. Moreover, several factors could help the speed at which technology is deployed and its compatibility with energy systems, other new technologies, and the constraint it may face socially, economically, and environmentally. There have been various technological innovations over the years because of the feed-in tariff which is economically feasible against interruption with systems due to political instability.

5.0 Challenges to low carbon future

5.1 Fluctuations in global energy price

Volatility in energy price movements affects both the traditional economic activities, formulated policies, and political support from the public. A higher conventional energy price environment initiates the development and deployment of new energy-efficient and costly technologies that have a superior chance of competing commercially on the open market. A lower market price in conventional energy increases the preference for cheap fuel and commercially available technologies (Ladislaw *et al.*, 2008). Both energy price fluctuation and new technologies highlight unique policy and investment strategies. For instance, higher fossil fuel prices shift consumer preferences toward carbon-free technologies such as alternative energy [nuclear and renewable energy (e.g., wind, solar, and hydropower)] based on cost. Alternatively, low prices for higher emission fuels such as oil sand, coal, and oil shale, trigger a low market appetite or incentive for the development and deployment of alternative energy and technologies. Given these conditions, it is becoming increasingly difficult to convince the public from using the conventionally cheaper technologies and fuel sources devoid of their impact on climate change and energy security (Ladislaw *et al.*, 2008).

Wesseh Jr *et al.* (2018) argue that changes in energy prices usually affect the global economy depending on the rise or fall of energy prices. Different studies have affirmed the connection between oil price and its effect on economic development, employment, exchange rates, and inflation. These effects are linked to most developed countries while other research connected the negative effects of energy prices to developing countries. Abdelsalam (2020) also affirmed the notion by demonstrating that the relation between energy price and economic growth usually has a negative effect on real products though has a considerable impact on welfare. Other research claims action on economic policy can also absorb the fluctuation in energy price shocks in relation to real products, while other research argues the effect of energy price shocks varies from country to country.

5.2 Policy/governance

Global leaders have projected the need for society to move to a low carbon future with several existing policies put in place to attain the transition from a carbon-intensive future by 2030, 2050, and beyond. Some industrial economies have included these pathways in their post-carbon strategies and intergovernmental bodies which explore the atmospheric GHG emissions (Rosenbloom, 2017). Bernauer (2013) identifies the gaps in political efforts in dealing with climate change and policies put in place to salvage the situation in the long term. There are global efforts in tackling climate change problems through negotiating and implementing global treaties which help in solving some climate problems, but various research identifies these policies to be at a slower pace. Further research discusses different issues which account for these challenges in achieving a global climate solution namely the institutional design that may help in overcoming various underlying problems in line with climate change. Second, policies that are a driving force at national and subnational levels can combat climate change. Third, Policy beyond state public opinion and civil society. Political uncertainty has been one of the major concerns for a low carbon future, government incentives and policies can quickly change over time and these changes can hamper effective collaboration in establishing long-term policy.

6.0 Guiding principles for achieving low-carbon transition

Climate change is already happening, hence, mitigating climate change and improving energy security are pivotal in sustainable development. The world energy demand is surging which may constrain future resources, and promote technological innovation over time, which will have unpredictable effects on the economic and political system (Ladislaw *et al.*, 2008). A sustainable strategy must simultaneously design a future transformation pathway where climate change and energy security are achieved. In this section, we deliberate on the guiding principles for developing and evaluating strategic options for a low-carbon (natural gas) and energy-secured future. These guiding principles presented in Figure 6.1 can be categorized into two namely effectiveness and political feasibility (Ladislaw *et al.*, 2008).

6.1 Effectiveness

The main drivers to measure the effectiveness of energy policies entail the capability of limiting and adapting to climate change events and strengthening global energy security through the availability, accessibility, and affordability of low-carbon energy. Mitigating the effects of climate change and achieving energy security comprise several important factors that underpin a successful policy framework including the adoption of a global and integrated approach, promoting without reliance on technological discovery, utilizing robust options for future scenarios, and adapting to developing circumstances.

6.1.1 Embrace global and integrated approach

GHG emissions underpin climate change consequences that are global in nature. The global community should coordinate actions to identify specific policies and mechanisms as transboundary challenges require a collective effort. Reduction in the concentration of anthropogenic emissions requires active participation and immediate action from all nations (Ladislaw *et al.*, 2008). The strategy for low-carbon energy should adopt a holistic approach to diversify energy while recognizing the interdependence of energy security.

6.1.2 Promote without reliance on technological discovery

Climate change mitigation and energy security require modern technologies for combating the effects of GHG emissions and strengthening the transition towards low-carbon economy. The decision-making process should take a long-term perspective and sustainable development to incubate a new technological innovation to take advantage of new opportunities emerging from climate change (Ladislaw *et al.*, 2008). The government may need to engage in public-private to share the cost and risks, demonstrate new technology feasibility, encourage research, science, and joint studies. However, it is important not to underestimate the R&D period needed from the developing technology to its commercial stage for deployment, and the limitation of the existing ones in the market. Policies must be implemented to drive and encourage innovation while allowing the market to evolve consistently to meet target objectives (OECD, 2007).

6.1.3 Utilize robust future scenarios and adapt to developing circumstances

The evolving circumstance of climate change and energy security short-run and long-run scenarios are unknown. The policies to tackle the issues of climate change and energy security must be characterized by flexibility and adaptability design to achieve desired results despite future climate change events (Bhave *et al.*, 2016).

6.2 Political Feasibility

The effectiveness of the policy framework is not sufficient to meet climate change and energy security goals, hence, requires political will to support the implementation of policies through a broad consensus. Such political feasibility requirements to address climate change and energy security issues include formulating a suitable time horizon, recognizing cost-benefit, incorporating into existing political priorities, and making room for development needs.

6.2.1 Formulate a suitable time horizon

Energy security and climate change will continue to exist in the foreseeable future beyond political philosophy and the business cycle. The policy framework to counter this problem should be flexible, adjustable, and sustained over the period. It therefore not feasible for policymakers to develop climate and energy policies that can stand the test of time—as climatic change continues to evolve and measures keep changing to achieve the set goals (Ladislaw *et al.*, 2008). This infers policymakers must constantly monitor, measure, and review the performance of long-term policies to meet set targets. This approach ensures a proactive strategy for tackling climate change and energy security through periodic evaluation.

6.2.2 Recognize cost-benefit

Mitigating the challenges of climate change and energy insecurity by changing production techniques and consumption has economic implications. Given such circumstances, policymakers should recognize and create opportunities for economic gains to offset the rising cost due to climate change policies. However, the eventual cost of doing nothing far outweighs the cost of mitigating climate change and energy security in the long run (Ladislaw *et al.*, 2008; OECD, 2007, 2011).

6.2.3 Incorporate into existing political priorities

Incorporating low-carbon policies into existing political priorities is difficult due to potential policy contradictions. Hence, it is essential to understand the bottlenecks and challenges in developing policies on climate change and energy security. There is a tendency for climate change policies to spill over into other areas such as trade, agriculture, energy, science, and technology. The nexus between these sectors should be considered to prevent overlapping and wasteful spending (Ladislaw *et al.*, 2008; OECD, 2011).

6.2.4 Make room for development needs

Historically, developed countries are largely responsible for large amounts of emissions since the beginning of the industrial revolution, leading to the current extreme climate events (CBCC, 2021). However, developing countries will be an influential source of emissions in the foreseeable future. The global effort in mitigating climate change should engage developing economies as it is crucial in implementing effective policies. Policymakers could break barriers and engage internationally in policy formulation to overcome geopolitical challenges that may affect national stability (Ladislaw *et al.*, 2008).

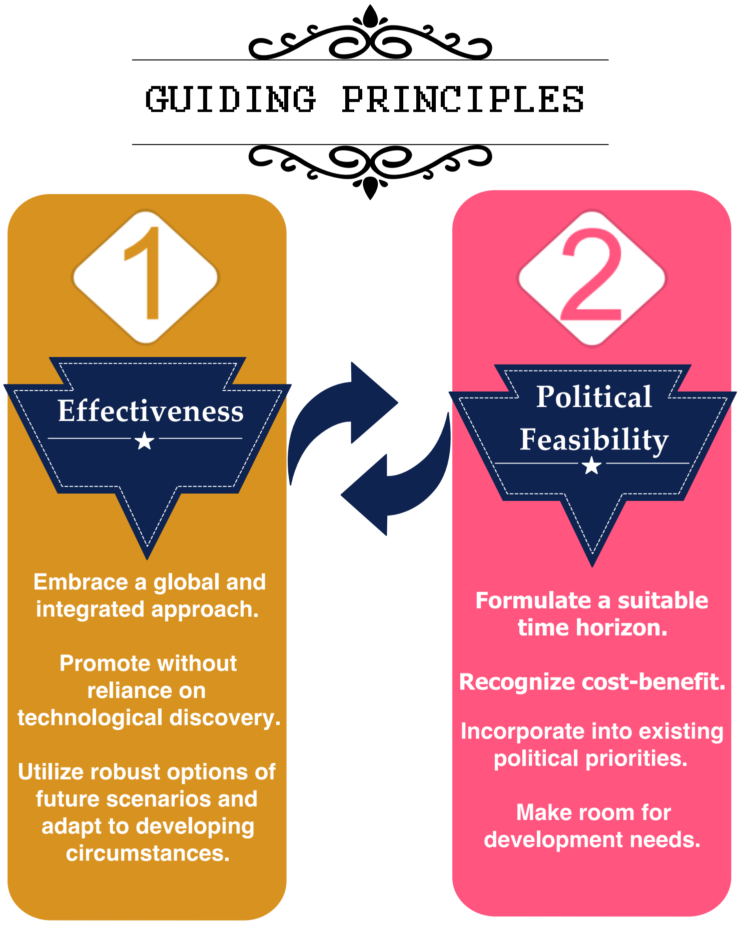

Figure 6.1. Guiding principles for achieving low-carbon transition. Source: Ladislaw *et al.* (2008).

7.0 Conclusion

Global climate change and energy security threaten human civilization, undermine economic development, and change the natural climate system, making it the most prioritized policy for the 21st century. Climate change and energy security are compounding challenges that increase over time exceeding most current global political cycles (OECD, 2014). Given this, policymakers and industrial players are forced to make compromises and complex decisions to adapt and manage climate change and energy security risks that we dangerously faced in a highly unknown future. The effectiveness and long-term implemented policies can be undermined by several variables over the long period. It is crucial for authorities and policymakers in decision-making to recognize the bottlenecks, challenges, and both internal and external variables that influence the policy environment to create the pathway to achieve a stable climate system and secure energy future (Ladislaw *et al.*, 2008).

Thus, there is a need for sustainable policies that ensure maximum social, economic, and environmental benefits in achieving universal access to modern energy and decarbonization. Access to clean energy is critical in achieving low emissions for growth and development. The need to achieve SDGs by 2030 may not be feasible because a large proportion of developing and poor countries will be without electricity due to the cost involved with migrating to clean energy and a low carbon future. Mechanism and technology which are vital in achieving a low carbon future should be paramount when decisions are made at the governmental level and among various stakeholders, and policymakers. The implementation of innovative approaches, regulations and planning in the energy sector including natural gas production will serve as a foundation for achieving a low carbon future.

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