



Petroleum dependence in developing countries with an emphasis on Nepal and potential keys

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ABSTRACT

The use of petroleum as a leading source across the globe accounts for overall energy demand. However, despite what may appear to be a declining contribution of petroleum to the world's energy supply, overall consumption of petroleum has, excluding oscillations attributable to a select number of happenings throughout the globe, been steadily rising until the present day. It is one of the many issues that is pressuring the globe to restrict the use of petroleum and move towards the use of renewable and clean energy resources. Although several initiatives are presently being carried out to find alternatives to petroleum, it is of the utmost importance for Nepal to be ready with distinct long-term and short-term strategies according to its circumstances as soon as feasible. When discussing the possibility of replacing the use of petroleum with that of alternative resources, it is necessary to discuss these possibilities in relation to certain countries because the possibilities for displacement vary from country to country. In this article, a comparative analysis of the usage, importance, and displacement of petroleum in Nepal is discussed. In addition, a full evaluation of the energy situation in Nepal has been presented, along with a discussion of the potential solutions that may be put into place in order to solve the issues that have surfaced. This paper discusses seven factors that motivate Nepal to displace petroleum and eight potential actions that can be taken to accomplish that goal. The main goal of this article is to look at the many ways Nepal could lessen its reliance on petroleum and move closer to finding good alternatives.

1. Introduction

1.1. Background

Petroleum is one of the leading sources of the world's energy with a 30.95% contribution to the total global primary energy consumption. The share of petroleum in global primary energy seems to decrease, however, the total consumption of petroleum neglecting some fluctuations caused by a few world events has been ever-increasing till now. The growth rate of petroleum consumption per annum in the time period 2011–2021 was 0.7% and the growth rate for the year 2021 alone was 6% [1]. However, there are no new large petroleum reserves found in the last decade. It is resulting in a gradual decrease in the net global petroleum reserves [2]. On the other hand, the price of petroleum, which was always seen very fluctuating, is actually increasing in the worldwide market. The average price of crude oil has increased by almost 426% in the last 35 years [1]. It is one of the several factors that is

enforcing the world to limit petroleum use and move towards renewable and clean energy resources. While many efforts are currently being made around the world to displace petroleum; it is very necessary for Nepal to be prepared with separate long and short-term plans according to its situation as soon as possible. Nepal is not in a position to immediately replace petroleum because of its complete reliance on the resource; no known fossil fuel reserves; the limited availability of alternative energy sources; and the unsettling state of the country's economy at the present time. However, in the international market, the crude oil price is seen as very sensitive to various world events like war, invasion, financial conditions, international policies, technological advancements, identification of new oil reserves, price of other competing energy resources, and other geopolitical issues [3,4]. The price of petroleum isn't only affected by the events happening in the petroleum supplier countries but also by the developing countries with large petroleum demands [5].

In the context of Nepal, there are many reasons for the continuous

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increase in the price of petroleum. The major reasons are: its dependency on the third country for import and refinery of crude oil [6]; transportation difficulty; severe dependence on petroleum and weak financial condition for switching to renewable energy resources. Fig. 1 presents the average price of crude oil and its trend with multiple world events, which indicates that the price of oils is in increasing order, although there were some fluctuations in past. Different world events are some of the major factors that determine the price of oils. For these reasons, it is clear that a developing country like Nepal which has poor economic conditions, limited infrastructure, and no reserves of petroleum will be more affected than other nations in near future [7]. Even in the present day, the purchase of petroleum accounts for the majority of Nepal's foreign currency expenditures. Additionally, the primary contributor to Nepal's persistently huge trade deficit is the country's continued reliance on imported oils. In the last eleven months, the total imports of Nepal were 17.63 trillion, where the contribution of petroleum was 16.6% [8]. When one considers the data collected over the past few years, it can be seen that the country has been using accumulated money for the purchases of petroleum. The utilization of foreign currencies has seen tremendous growth as of late. This pattern is becoming more common, and the difficulty associated with its displacement, if not addressed in a timely manner, will soon bring about a precarious circumstance for those who are living in this area. Therefore, the regulated use of petroleum will be a start in the mid-way solution between the existing circumstance of not being able to instantly replace petroleum and bad hits from the delay in that attempt.

Nepal must have the economic capacity and sustainable growth, accounting for environmental impact, efficient use of energy, international support and responsibility, and other similar factors in order to successfully replace petroleum. These are a few driving forces that play here. It is a difficult and time-consuming task itself to replace an energy source that people's lives depend on while simultaneously increasing the utilization of new energy. It requires a tremendous amount of energy to force out the dominant fossil fuels. It has been seen that renewable energy production must be increased eightfold to completely displace fossil fuels by the year 2050, provided that the increase in energy demand isn't more than 50% of the 2020 energy demand level [9]. Because

of this, it is desired for the nation to move forward with a clear long-term policy and plan to regulate the use of petroleum and replace it with the idea of proper energy conversion. This would be a step in the right direction for the country. The displacement of petroleum has become an issue that is difficult and hard all around the world. Even though several nations throughout the world have set the major objective of totally displacing the use of petroleum for the net zero emission goal by the year 2050 [10], the progress that has been made thus far does not appear to be adequate and sufficient [11]. The energy sector, especially fossil fuels being the major resource, contributes to three-quarters of global emissions. Improved finance programs for clean coal, carbon capture, and energy storage technologies are necessary for many nations to reduce their environmental impact [12]. In Nepal, the topic of alternative fuels to replace petroleum is brought up every time there is an announcement of an increase in the price of petroleum. However, finding a suitable alternative to petroleum has been a very difficult issue.

Even though the Coronavirus reduced global consumption by around 9% in 2020, the amount of oil consumed all around the world each day was still 91.36 million barrels (119.24 L in 1 barrel), however, it was one of the largest declines in the history of oil consumption. The temporarily declined oil consumption bounced back by 6% growth in the year 2021 [1]. By the year 2030, the world will have reduced its daily consumption of petroleum to preserve the environment, ensure the efficient use of nonrenewable petroleum resources, and put a cap on carbon emissions. The goal is to keep consumption below 105 million bpd in the worst case, i.e., even if the net zero path is missed [13]. Petroleum, on the other hand, has been utilized for hundreds of years and its use is not confined to a single sector. As a result, its control and displacement are not simple tasks. The most important application for petroleum is in the transportation sector. It has not yet been accomplished to create a reliable and mature alternative fuel that can easily take the place of petroleum in the transportation industry. Several studies have shown that if electricity is used to its fullest potential in the transportation sector, global energy use will drop significantly compared to what it is now, because of the efficiency of the electrical energy provided that the electricity is generated from a relatively efficient resource like hydro-power [14–16].

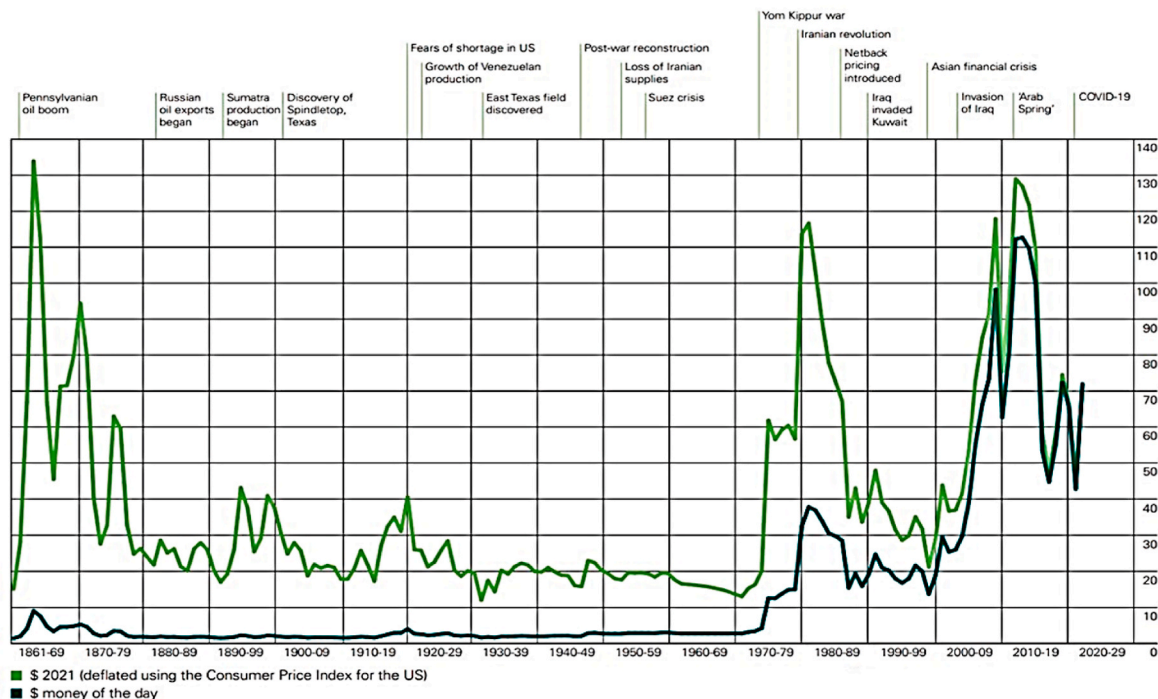


Fig. 1. Average price of Crude oil from 1861 to 2021 in USD per barrel, and the world events [1].

1.2. Literature review

In the past, several research studies have been conducted that have explored the dependence of various nations on energy and petroleum. These studies have been found in a variety of archives. The Asian Development Bank Institute released a study [17], in which the author/s explored the macroeconomic implications that changes in the price of oil have on both developing and industrialized economies. According to this study, the effect of changes in the price of oil on the growth of GDP in developed oil importers is far less severe than its influence on the growth of GDP in developing economies. Similarly, AusAID carried out research into the Pacific region's macroeconomic impact because of the rising energy costs [18]. Research that was carried out by Cambridge Econometrics [19], evaluated the amount of reliance that the 27 member states of the European Union (EU) (EU-27) have on imported oil, as well as the hazards that this places on both the environment and their supply chains. According to the findings of this study, crude oil and other products derived from petroleum account for close to half of the EU's total energy consumption. This need is driven mostly by the transportation industry, and more specifically, by the automobile industry. According to research [20], natural gas is the most important primary energy resource in the euro area, coming in second only to petroleum-based goods in terms of importance. It is by far the most important source of energy in the industrial sector, and more than 90% of the gas consumed in Europe comes from outside the region. Bella et al. conducted research to determine the possible impact that disruptions to the supply of natural gas in Europe may have, and they also addressed the economic situation in European countries [21].

In a similar manner, research [22] evaluated the economic diversification in oil-exporting Arab nations; the findings of this analysis revealed that other industries need to be established so that they may take over when the oil and gas industry dwindles due to the fact that oil is an exhaustible resource. Additionally, a wider economic diversity would liberate growth that creates jobs, would increase resistance to the instability of oil prices, and would better the chances for future generations. Research has been carried out not only for developed nations but also for developing countries in a variety of different ways. Haider Mahmood states that increasing oil exports may also be good for the environment of oil-exporting countries, but oil imports could be discouraged to stop CO₂ emissions from their use [23,24]. Alex Antwi conducted research into the effects that changes in the price of crude oil have on Ghana's inflation rate and exchange rate [25]. Alam et al. [26] examined the South Asian countries' reliance on energy and proposed a certain need for a regional solution. This paper argues that a regional energy trade will create a mutually beneficial platform for the effective utilization of natural resources, which will increase the reliability of power supply, build economies of scale, enable mutual support during contingencies, transform sectors on a large scale, and contribute to economic growth. The analytical framework that this paper provides is based on the data that was collected from the region. In the same vein, the authors of [27], evaluated the economic growth of Bangladesh in relation to both the natural gases that were produced locally and those that were imported. The authors of this study emphasized the importance of cross-border gas importation and the infrastructure connected with it in order to support the activities related to its growth.

On the other hand, Yasemin et al. examined the dynamics of how changes in oil prices affected Turkey's current account during the period of time between 2004 and 2015 by employing the rolling window technique [28]. Similarly [29], addressed how fluctuations in the price of oil affect the level of inflation in Pakistan. According to research conducted by Soligo et al. [30], China's rising oil import requirements and the physical constraints of its refining sector suggest that China will become increasingly dependent on the same energy sources as other industrialized economies in the future. This could make its strategic goals in the Middle East more closely aligned with those of the West in that area.

1.3. Research gap and objectives

From the literatures taken in the previous sub-section, it is clear that the study should be different for different nations. When discussing the prospect of replacing the uses of petroleum with those alternative resources, it is necessary to discuss the possibilities in relation to certain countries because the possibilities for displacement vary from country to country. There are a number of factors that play an important role in this transformation, including the following: (a) the availability of alternative sources such as renewable energy resources; (b) the policies and regulations of the government; (c) the economic factors of the countries and the situation of energy justice; (d) the condition of the adoption of technology within those countries; (e) social acceptance and local perceptions; etc. As a result of these points, it is possible to see that there are two primary factors that have a direct impact on this movement if we are specifically talking about the displacement of petroleum. These factors are: (a) the geographical condition of the area and the availability of resources, and (b) the economic status of the nation. Countries will prioritize the use of resources that they already possess; for instance, countries that have access to renewable energy resources will make use of these resources as their primary source of energy, whereas countries that have access to oil products, such as those in South and North American Countries and Middle east countries, use oils as their primary source of energy. Whereas countries with abundant coal reserves such as Australia, China, and India meet their primary energy demand with the major share of coal [31]. In a similar vein, nations that are in a healthy economic position are in a better position to take the initiative because they are better equipped with the technologies and infrastructure necessary to adapt to the transformation. Nations with a weak economy, on the other hand, will concentrate on their fundamental issues first rather than this transformation. Because of this, it is of the utmost importance to do research on how this change affects each country and what opportunities and challenges it brings.

Nepal is a growing country that has a significant potential for the resources of renewable energy such as hydro power plants, solar energy, and wind energy; nevertheless, the country does not have any reserves of petroleum. On the other hand, Nepal is a landlocked country that is encircled on three sides by India, and one side by China, and is landlocked from all other countries. As a result, when discussing the topics of energy transportation and Nepal's cooperation with other nations, there are aspects of both positive and negative that pertain to Nepal. On the basis of these geographical and economic circumstances, Nepal is completely different from other nations; if we need to understand the condition of the country, it is vital to assess the feasibility of the petroleum displacement for Nepal individually. In this article, a comparative examination of the use, importance, and displacement of petroleum in Nepal has been examined. The focus of the analysis is on the country's economy. In addition, a comprehensive review of the energy situation in Nepal has been provided, along with a discussion of the possible solutions that may be implemented in order to address the problems that have arisen. As is the case in the majority of other nations, the rising cost of oils is having a significant negative effect on Nepal's national economy, in addition to raising worries about the country's influence on the environment. The primary purpose of this article is to analyze the potential solutions that could reduce the amount of petroleum that is used in Nepal and work toward replacing those products in the not-too-distant future. Also, it is to give extensive information on the influence that rising prices for petroleum have had on the economy of the nation, as well as the impact that rising prices have had on the various sectors of development. Furthermore, this paper presents a list of measures that could be used to reduce the amount of petroleum used in both the short and long term.

1.4. Structure of presented article

This paper begins by providing an overview of the context, followed

by an introduction to the situation. The present status of energy supply and reserve worldwide are discussed in Section 2. The primary source of energy in Nepal is discussed in Section 3, along with the current state of the country's energy infrastructure. In Section 4, the author/s go into detail about the factors that led to the decision to switch away from utilizing oils in Nepal. In Section 5, author/s explore the different activities that can be carried out in the Nepalese scenario. A detailed discussion on the topic and related research fields has been presented in Section 6. In the last section, conclusions have been made.

2. Status of energy production and consumption worldwide

As a result of the widespread use of industry and automation in today's world, every member of the human race is entirely reliant on various forms of energy, most notably electrical energy and mechanical energy. Every task requires a certain amount of energy. The status of energy inside a country is directly proportional to the level of prosperity the country has. The rising rate of development has resulted in an increase in the need for energy, which in turn has led to an increase in energy consumption at an alarmingly quick rate. The trend of the consumption of energy and the production of energy from various energy sources throughout the world is presented in Fig. 2. The trend of growing energy consumption can be seen in Fig. 2 (a), which depicts the trend of primary energy consumption by region in EJ. It would appear that the pace of growth in energy consumption in the Asia-Pacific area is far greater than that of any other region. Because of the tremendous pace at which the industrial revolution and automation have been taking place in the countries of Asia and the Pacific in the last few decades, consumption has increased at an alarming rate. The instances of industrialization and economic revolution that may be discussed here are those that took place in China, Korea, Singapore, India, and so on. Nevertheless, it appears that the use of primary energy has been similar for a long period in both developed and under-developed regions.

Similarly, the production of various sources of energy in different regions up to the current day is shown in Fig. 2(b–e). The summary reveals that the generation of energy resources is also increasing at a high rate. This is demonstrated by the fact that, when compared to the production of other types of resources, oil production in the Middle East and the Commonwealth of Independent States (CIS) appears to be on the rise. However, the amount of oil extracted in Asia and the Pacific is not very significant. On the other hand, the quantity of other minerals extracted, and the growth of electrical generating plants appear to be rather aggressive. As can be seen in Fig. 2(c), the amount of coal being extracted is going down in certain places, whereas in the Asia Pacific it is going up dramatically. Similarly, the pace of natural gas extraction in Asia-Pacific and the Middle East is significantly higher in comparison to that of any other area, even though North America is the region that produces the most natural gas overall. The rate of increase in electricity production is not noteworthy in other areas, but it is too high in Asia-Pacific. This is one of the most important changes that can be seen in how energy is made.

The activities that are connected to the exploitation of energy systems, economic success, the development of infrastructure, and so on are the primary factors that determine energy consumption. The extraction of energy is mostly reliant on the availability of resources, as well as national policies, economic activity, and other such factors. When we discuss the rate of energy extraction or production from a certain nation or region, the local availability of the resource that provides that energy is the most important factor that must be taken into consideration. After that comes the phase in which worries about the economy and the environment play a significant role. It is clear by looking at data from BP Statistical [1] that Russia, North America, and the Middle East are the regions of the world that use the most crude oil and natural gas compared to other countries. The availability of particular types of energy resources in a nation or region is a significant factor in this phenomenon, and it is one of the primary reasons. Why do these countries,

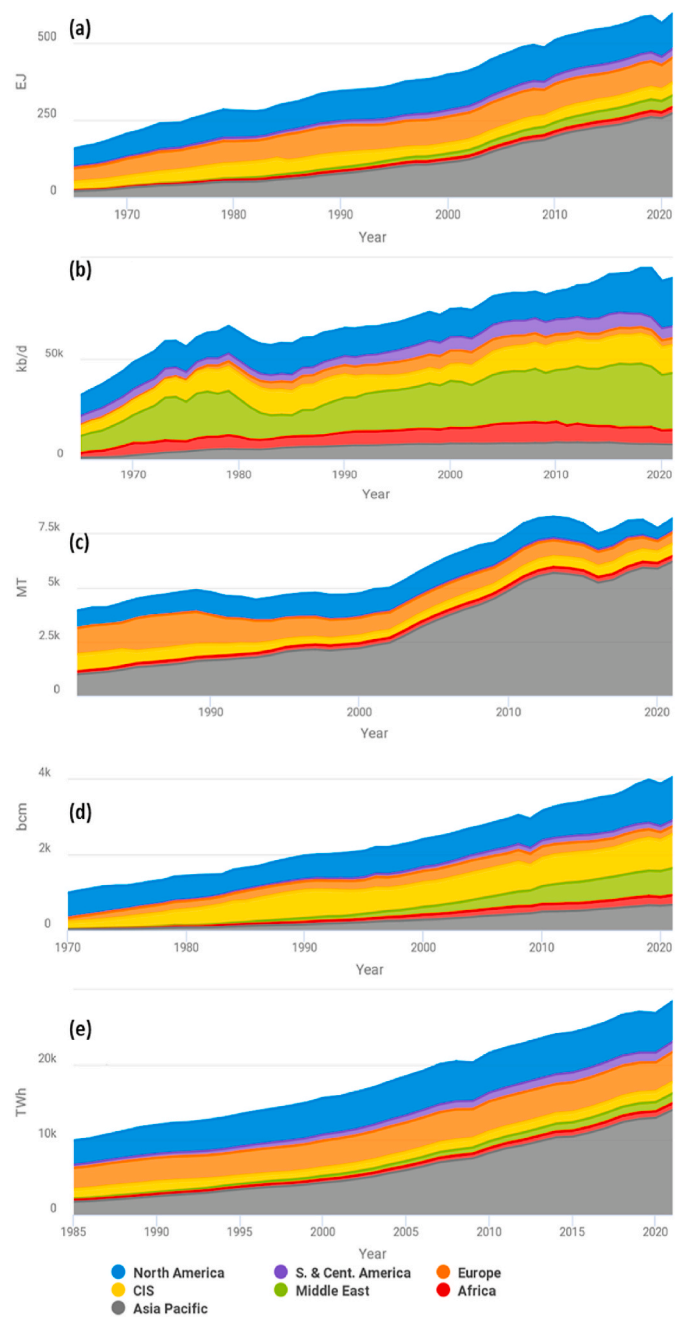


Fig. 2. Trend of (a) primary energy consumption by region in EJ, (b) oil production by region in kb/d, (c) coal production by region in MT, (d) Natural gas production by region in kb/d, and (e) electricity production by region in TWh [1].

which each have significant reserves of several types of energy resources, choose to devote a disproportionate amount of their consumption to one particular kind of energy resource rather than to others. Fig. 3 provides a visual representation of the crude oil reserves present in each of the world's many areas. According to the data in the figure, the Middle East has a significant amount of untapped crude oil reserves. South and North America have a significant reserve of crude oil in their respective countries. When compared to the other regions, the reserve potential that Europe possesses for crude oil is the lowest. The countries with a high reserve of energy resources are also exporting the resources to other countries/regions, which can be seen in Fig. 4. Fig. 4 shows the key oil trade movements occurring all over the globe in the unit of million tons, from which it can be seen that the countries that have

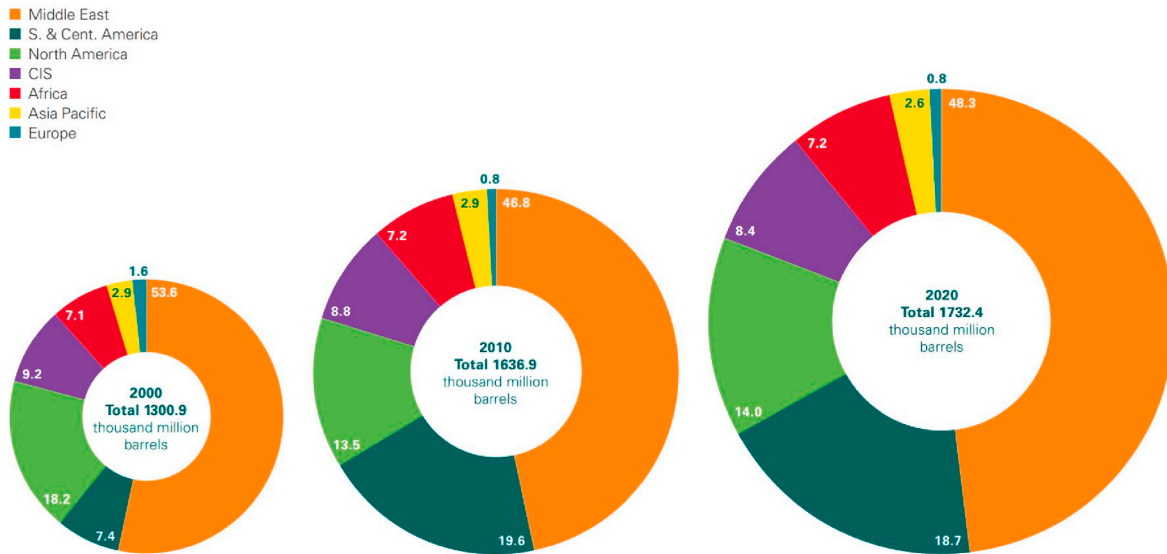


Fig. 3. Distribution of proved reserves of crude oil in 2000, 2010, and 2020 [2].

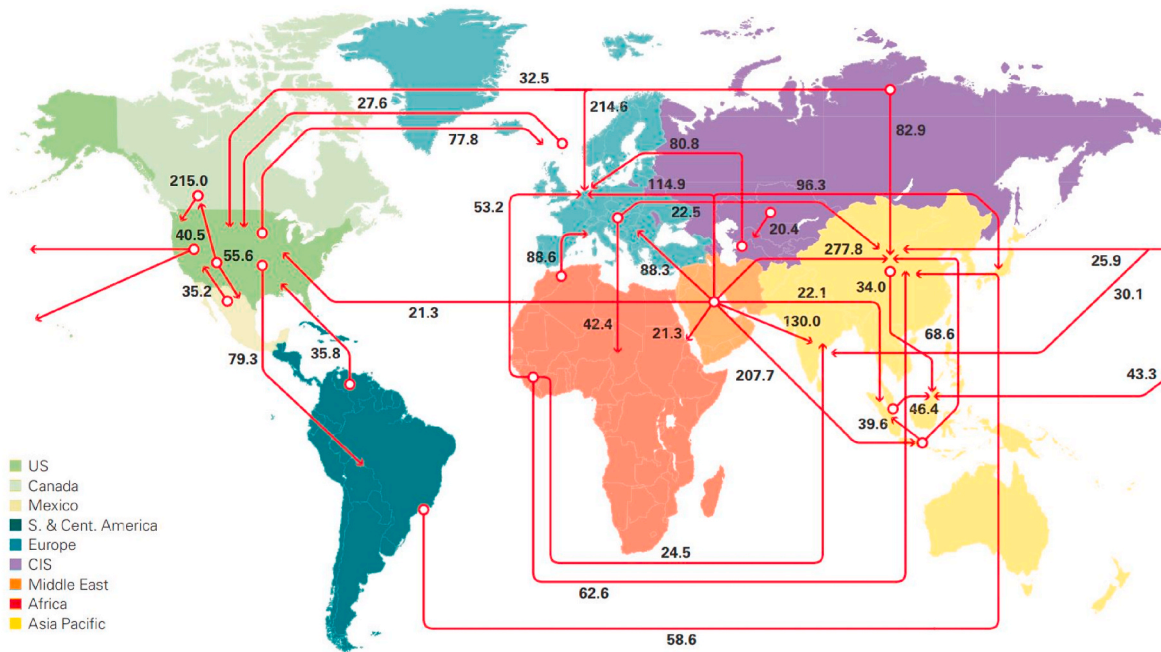


Fig. 4. Major oil trade movements worldwide in 2021 (in million tons) [1].

larger reserves are the ones that are exporting the products. This trading of energy resources takes happens either only inside the region or, furthermore, between the various regions. It would appear that the Middle East and CIS are the most significant exporters, whereas the Asia-Pacific region is the most significant importer.

3. Current situation of Nepalese energy supply

The average use of energy on a per capita basis in Nepal was 1530 kWh in 2019. This is fairly low consumption compared to other countries, due to the fact that the global average consumption of primary energy per person was 20,941 kWh in that year [32]. The key sources of energy supply in Nepal are presented in Fig. 5. Traditional forms of bioenergy are not sufficient to fulfill the ever-increasing requirements for power in Nepal’s residential, commercial, industrial, transportation,

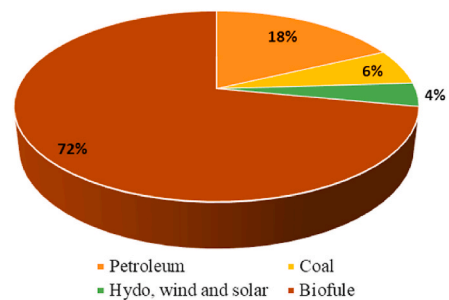


Fig. 5. Proportion of primary energy resources in Nepal [30].

and agricultural sectors. However, the conventional forms of bioenergy continue to make up the largest portion of the total supply. In 1990, bioenergy accounted for 94% of the total supply. However, due to the rapid expansion of the use of fossil fuels and the importance placed on hydropower, the percentage had fallen to 72% by 2019 [33]. During this time, there has been a considerable expansion in the supply of petroleum. Petroleum was responsible for 4.21% of Nepal's total energy consumption in the year 1990. Since then, that number has steadily climbed to 17.52% in 2019. As a direct result of the enormous growth in the number of vehicles, the supply of petroleum has increased by a factor of two in just the last five years. The fact that Nepal does not generate any of its electricity from coal at the national level, and is very appreciable since coal is responsible for the generation of approximately 36% of the world's electricity [1]. However, its use in the commercial and industrial sectors of Nepal is significant. Most of the nation's electricity comes from conventional and environmentally friendly sources (i.e., water). Nepal, on the other hand, receives only 4% of its total primary energy supply from hydropower and renewable sources [33], whereas the world receives approximately 13.5% of its total energy demand from hydropower and renewable sources [1]. This makes it quite evident that Nepal's utilization of renewable energy sources and electrical power is quite low. The demand for primary energy in Nepal has increased by 72% between 2000 and 2019. To fulfill this demand, the amount of fossil fuel has increased by 245%, while the amount of energy that comes from renewable sources and bioprocesses has increased by just 49% [34]. Because of this, it looks like Nepal will have a hard time meeting the global goal of using fewer fossil fuels.

When looking at Nepal's primary energy consumption on the basis of sectorial use, it would appear that the residential sector (cooking, lighting, and heating purposes) uses the most energy out of all the sectors, accounting for approximately 75% of the overall consumption [33]. Firewood and other types of biofuels cover the majority of Nepal's total residential energy consumption. Despite the fact that households consume approximately 45% of the total electricity available [35], electricity accounts for only a small portion of total residential demand. The use of electricity in the other sectors is minimum, electricity contributes only about 2%, 5%, 10%, and 14% of household, agriculture, commercial, and industrial sector's demand respectively. It highlights the fact that the amount of electricity used is relatively low across the entirety of Nepal. Almost all fossil fuels are used for transportation. Fossil fuels and traditional forms of bioenergy meet the remaining energy demand of the aforementioned industries. The use of bioenergy is at its highest level for residential uses even at the present time, it is reasonable to believe that the number of individuals who cook with petroleum gas has increased far more. In recent years, there appears to have been a rise in the amount of clean power that is being used in both home and commercial settings. Fig. 6 shows how different types of customers share total electricity available in Nepal.

4. Motivation for the displacement of petroleum in Nepal

The gases that are emitted as a result of the usage of oils have a direct

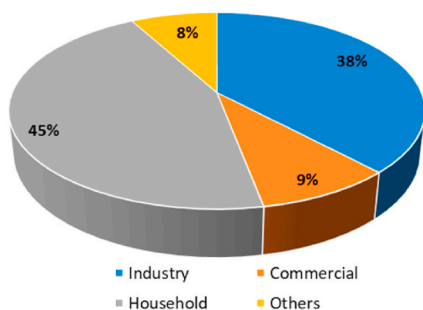


Fig. 6. Sector-wise proportion of electricity in Nepal [32].

influence on a variety of aspects of the environment, including the air, the temperature of the environment, and the ecological systems. On the other hand, the cost of energy accounts for a significant amount of a country's expenditures and the national economy; the rising cost of petroleum products has a detrimental impact on the concept of sustainable development. As a result of the detrimental effects, it has on the environment as well as the constraints it places on economies, numerous nations are discouraging its use and making plans to find an alternative to it in the not-too-distant future. However, the influence and the consequences may vary from one nation to another; it may have distinct repercussions in wealthy nations compared to poor nations. As a developing landlocked country with no reserves of oils, Nepal has no choice but to make massive use of these products brings a set of complications. In this section, the motivations behind replacing petroleum with various mains of alternate sources have been examined in detail. This overall assessment and discussion focus specifically on the Nepalese scenario.

4.1. Fluctuating price of crude oil and uneven distribution of petroleum reserves

It is observed that the price of a barrel of crude oil is in an increasing trend since 1985 and reached a peak of 109.08 dollars (Dubai dated) in 2012. The current price of a barrel of crude oil is almost six times the average price of a barrel on the worldwide market in 1986 [1]. The price of crude oil has been always fluctuated and very sensitive to many factors and world events. These price fluctuations are enough to produce significant impacts on countries having weakly stable financial conditions, like Nepal [36,37]. Such countries suffer next few years to get recovered. Furthermore, on the international market, there are sufficient grounds for the rapid growth in the price of petroleum goods to continue in the foreseeable future. One reason for the petroleum price fluctuation and rapid growth is its non-uniform distribution of reserves over the globe. This has made it dependable in various political and non-political policy-related global issues. The regions like the Middle East, North and South America, and CIS have much higher petroleum reserves whereas highly populated regions like Asia and Africa, and Europe have comparatively very low petroleum reserves. This non-uniformity in the petroleum reserves with respect to population and area is presented in Table 1. The rise in price has been further attributed to supply and demand factors. Although there have been some shifts in price in the past, the average price and its trend show that the price of oils is now on an upward trajectory. This is despite the fact that there have been some changes in the price in the past. Since the year 2019, the price has been steadily climbing at a rapid pace, which is significant for economies in other parts of the world. In spite of the fact that it is a non-renewable source of energy, petroleum is currently the dominant source of energy in the globe. This is due to the fact that there are finite supplies of oils all over the world. If global consumption of petroleum remains at its current level, experts estimate that the world's total oil reserves will only last for another 50 years [2]. On the international market, the price

Table 1
Distribution of petroleum reserves across the world (Data taken from Ref. [2]).

Regions	Ratio of Petroleum Reserves to Population (Barrels per person)	Ratio of Petroleum Reserves to Area (Barrels per Sq. km)
Middle East	1754.70	115975.22
S. & Cent. America	519.15	17610.75
North America	404.13	9830.43
CIS	487.33	7177.66
Africa	88.59	4119.20
Asia Pacific	9.55	957.21
Europe	22.56	1335.95
World	198.10	10934.88

of petroleum will almost certainly continue to go up in the next years.

4.2. Dependence on petroleum and current trade deficit

Nepal is and will continue to be totally dependent on either India or some other country to meet its petroleum needs. Due to the fact that India's reserves and extraction are extremely low in comparison to the country's demand for petroleum, India must rely on imports to meet the majority of its total consumption. These imports come from countries in the Middle East, Russia, Europe, and the United States. Even in the present day, the purchase of petroleum accounts for the majority of Nepal's foreign currency expenditures. Nepal delivered 591,700 kL of gasoline, 1,696,202 kL of diesel, and 477,752 metric tons of LPG gas in the last year alone, which represents an overall rise of over 14% in comparison to the previous fiscal year [38]. In comparison to the year 2015, these numbers are approximately twice as large. During the first 11 months of the current fiscal year, petroleum with a value of 2 trillion 93 billion was imported [8]. This represents an increase of approximately 88.7% when compared to the same period during the previous fiscal year. It was about 16.6% of Nepal's total imports (17.63 trillion Nepalese rupees) for that time duration.

4.3. International obligations

Since the early years of the previous decade, the industrialized nations of the world have been exerting a great deal of effort in order to meet the objective within a predetermined amount of time for the purpose of supplanting petroleum. In this endeavor, China and many European countries, which have fewer reserves of oil than the rest of the world, are ahead of everyone else. Many international agencies have already announced targets (such as net zero emission, 2050) to limit emissions and protect the environment through sustainable and clean development strategies. These strategies directly discourage the use of fossil fuels. Furthermore, when there is less petroleum available in the future, it is safe to expect that these measures will be more comprehensive, stringent, and mandatory. This is a reasonable assumption to take initiative toward petroleum displacement. Since a delay in the process could lead to more international pressure on the country in the future, it is important to have clear rules and management for it as soon as possible.

4.4. Potential for adequate renewable energy sources

Strong visionary policies have helped small countries like Singapore, which do not have significant potential for renewable energy sources, take the lead position in Asia in terms of energy transition [39]. Although Nepal has the potential to generate adequate hydropower, a country that is rich in water resources, must rely on renewable energy in order to fulfill its demand for electricity. The fact that practically all of Nepal's electricity comes from renewable sources like water and the sun, even though the rest of the globe relies heavily on non-renewable sources of energy like oils and coal, is a significant reason for optimism. The results of several studies indicate that Nepal has the ability to generate nearly 42,000 MW worth of hydropower at a level that is both economically and technically viable. From a simple energy equivalence calculation, it is seen that Nepal needs to build hydropower projects with a total capacity of about 2425 MW to displace all of the oils with electricity at current consumption. The construction of hydropower projects with a combined installed capacity of 4200 MW is currently underway but at varying phases (under construction, planned, and proposed) [35]. However, since Nepal is a mountainous nation and the majority of its water resources are found in mountains [40], it is important to speak about how global warming and other environmental activities are affecting glaciers and their trend when discussing the long-term planning of hydropower projects. In their study, Talukder et al. [41] spoke about the Himalayan glaciers and the state of the globe.

According to the authors of that research, global warming has hastened the melting of Himalayan glaciers, endangering hundreds of millions of people and having severe effects on the region's planetary health. However, this paper's main focus is on the energy sector; the authors' discussion on energy security and its implications for the future is its focus. Since the majority of the hydropower facilities in Nepal are glacier-dependent, melting glaciers might impair energy production by reducing, greatly changing, and creating unpredictable river flows. In addition, unforeseen catastrophes like glacial-lake outbursts may cause flooding and landslides [42], which can harm both people and hydro-power infrastructures and threaten the nation's energy security. Building hydroelectric projects using dams as the foundation might be a useful way to combat issues with water flow irregularities. Additionally, by temporarily obstructing them, it may aid in reducing the direct effects of floods and landslides. An environmental impact assessment (EIA) must be done to look at the impacts of these big dams on the ecosystem and make sure there aren't any that can be seen. The negative effects may be reduced with the right research and planning, but there are still certain challenges in the construction of hydroelectric projects in such a region. The major concern right now, however, is the availability of resources; the nation should profit from them through smart planning. If the government can harvest the resources responsibly, it will be able to combat the present non-renewable resource and global warming issues. On the other hand, Nepal is situated in a favorable geographic region with plenty of sun and wind. Recent times have seen a preference for solar energy among consumers and proponents of private energy. As a result, it seems that a significant increase in the nation's need for clean energy has occurred. As a result, the growth, use, and prioritization of power generated from reliable renewable energy sources have shown the feasibility of the petroleum substitution.

4.5. Severe atmospheric effects

The emission of greenhouse gases in Nepal is estimated to be 60.07 million metric tons of CO_2 equivalence in the year 2019. The CO_2 emission alone reached 23.07 million MtCO₂e in that year. The CO_2 emission, which has been increasing significantly in recent years, is expected to reach 34 million MtCO₂e in 2030 and 79 million MtCO₂e in 2050 [43]. Nepal's emissions are negligible (about 0.05% of the world's emissions) when compared to the developed countries' emissions and the rest of the world's [44], but these emissions are expected to continue to rise. The increased greenhouse gas emissions caused by the use of petroleum will keep going up as long as the amount of petroleum used keeps going up. Nepal possesses an abundance of natural resources as well as a wide variety of living things. The effects of hazardous gases released by the use of petroleum and fossil fuels, as well as the effects of climate change, will have the greatest negative impact on glaciers, natural resources, and biological resources. Many kinds of creatures have vanished from our environment, and there are numerous examples of this. Floods, landslides, and droughts that do not occur during their typical seasons are further examples of the consequences that climate change has had on the country. Therefore, there is both a chance and a challenge for Nepal to become a model for the rest of the globe in the endeavor to curb the emission of dangerous gases in order to safeguard them. Also, Nepal is composed of dominantly agrarian societies, and climate change effects are felt by the majority of the population. It is important to avoid these kinds of disasters.

4.6. Opportunities for infrastructure development

There are not nearly enough development facilities in Nepal for the country to support its status as a country focused on development at the present time. Many kinds of infrastructure and buildings are being built. It would appear that in the not-too-distant future, those infrastructures will not be up-to-date, and the cost will continue to be high if the operation of those infrastructures depends on fossil fuels. For instance, if

the country builds an electric railway rather than a coal-powered train, it will be more environmentally friendly and it will be sustainable onwards. It means that the country faces both a challenge and an opportunity when it comes to the construction and operation of the infrastructure that will soon be built, and that challenge and opportunity is to take into consideration while implementing green and renewable energy, low emissions, low environmental impact, and the concept of sustainable development.

4.7. Early effects

Despite the fact that the rate at which petroleum is being consumed is on an upward trend, it appears that the future of petroleum will only last approximately 50 years based on the global petroleum reserves and the present consumption rate. In the present day, the consumption of petroleum, which is the substance that is utilized the most all over the world, is likewise consistently growing in Nepal. The amount of petroleum consumed has increased by more than a hundred percent in the last five years [8]. On the one hand, it will increase the amount of expensive energy that is consumed, and on the other hand, it will increase the reliance on petroleum. If the community continues to rely on sources of energy that have a finite lifespan until late in the game, then it is possible that our constructed infrastructure will not be up-to-date and sustainable in the near future. This may mean that the infrastructure will not be financially viable or justifiable. Furthermore, the displacement and transformation of energy, which is necessary for the survival of people, is a difficult and time-consuming task in and of itself. If the country waits on replacing oil on purpose, it will have to deal with all of its bad effects in the future as well. Therefore, taking the petroleum displacement initiative as soon as Nepal can, would be a very wise decision to make.

5. Potential actions that can be implemented in the Nepalese scenario

Different nations are making different attempts to replace non-renewable energy sources, including petroleum. Energy supply patterns, national fossil fuel reserves, the accessibility of renewable energy sources, and the political and economic conditions of the nation are all elements that directly affect this. Nepal's measures to replace petroleum may differ from those of other nations. For example, because fossil fuel reserves are not large and renewable energy is given special attention in national policy, Europe is ahead of the world in the displacement of petroleum; the average annual growth rate of oil consumption for Europe is -1.9% in the time period 2011 to 2021 [1]. Whereas in Nepal, the need for petroleum has recently been rising quickly. It is not viable to replace petroleum quickly, and delaying the displacement is not a smart idea either because of the requirement to import all petroleum, the ongoing price increase in the global market, and the fragile economy. The lifestyle and strategy of progressively reducing petroleum usage appear to be the best mid-way solution. In this section, the potential strategies that can be implemented in Nepal in order to reduce the use of petroleum have been discussed in detail.

5.1. Hydropower development

Since it appears that the majority of the consumption of petroleum in Nepal occurs in the areas of transportation and domestic support, it is reasonable to anticipate that it will be possible for electric power to fulfill this role. Electricity is an essential source of energy since it can be used productively and for a variety of purposes; its transmission is highly efficient; its loss is relatively low; it is simple to both manage and store. Electricity is required in relatively small amounts (in terms of total primary energy balance) in the process of petroleum displacement since its utilization is quite efficient. The amount of petroleum that Nepal has consumed during the past 28 years, it would appear that it has increased at an exponential rate. Consequently, in the event that the demand for

oils (gasoline, diesel, and LPG) continues to rise over the next 20 years, it would appear that the amount of their consumption will be 3.9, 3.5, and 5.3 times (respectively) more than the current level. Nepal needs to meet this increased petroleum demand with the generation of hydroelectricity. With simple energy equivalence relation of petroleum energy and electrical energy considering their overall use efficiency, the hydropower plant capacity required to meet the petroleum demand after the next 20 years has been calculated. It has been seen that hydroelectric power plants with a total installed capacity of 10,480 MW need to be built to replace the energy that comes from oil production. Out of which, approximately 957 MW (about 5448-GW hours of energy), 4153 MW (about 23,647-GW hours of energy), and 5370 MW (about 30,579-GW hours of energy), will be required to replace the gasoline, diesel and liquefied petroleum gas respectively after next 20 years. It is evident from the general projection that 13,808 GW-hours of electrical energy will be required to replace the current petroleum demand. However, if the demand for petroleum does not expand at the same rate as it did in the preceding 20 years, then the amount of energy necessary will be less than what was specified. The assumptions made in these simple projections are: (a) petroleum demand growth will follow the trend of the last 40 years for the next 20 years, (b) overall energy efficiency of electricity (for electric vehicles) is taken 90%, (c) overall petrol and diesel use efficiency taken 30% and 40% respectively, (d) LPG and electric cooking stove use efficiency is taken 55% and 75% respectively, and (e) plant capacity factor for hydropower plants is taken 0.6. Considering these assumptions, the information on the installed capacity of the hydropower projects, electrical peak demand, and the rating of hydropower required to replace the oil has been listed for the last 25 years and prediction has been made for the upcoming 20 years (in Table 2). In light of this, and taking into account the potential of Nepal's hydropower, it may be deduced that Nepal possesses the technological capability of substituting hydropower for oils.

The power plants that are now operational have a total installed capacity of 1451 MW, and these plants have provided around 8878 GW-hour of electricity to date [28]. During the current fiscal year, many new hydropower plants were developed by Nepal Electricity Authority (NEA) and Independent Power Producers (IPPs) and many small solar power plants were connected through private efforts and the Alternative Energy Promotion Center (AEPC)'s assistance was put into operation. As a result, it is possible to estimate that the total installed capacity has reached more than 2300 MW. However, because the majority of the hydroelectric facilities are of the "run-of-river" type, the production of electricity drops by nearly one-third during the dry season. As a result, the first and most fundamental step toward replacing petroleum will be the government's priority for the development of major hydropower projects that are based on reservoirs in order to provide sufficient generation of energy even during the dry period. Also, the work that has been planned to continue building electrical infrastructures, such as transmission and distribution lines and the substations that are needed

Table 2

Projection of installed capacity of the hydropower plants, electrical peak demand, and the hydropower required to replace the oil.

Years	Installed Capacity of Hydropower Plants (MW)	Electricity Peak Demand (MW)	Hydropower required for Petroleum Displacement (MW)
1995	253	244	232
2000	361	352	340
2005	557	558	407
2010	705	885	865
2015	851	1291	1094
2020	1451	1408	2425
2025	1834	1686	3852
2030	2375	1942	5620
2035	2996	2198	7822
2040	3698	2455	10,480

* Bold data are the trend line projections.

to meet the demand for electricity mentioned above, should be done. However, as discussed in Section 4.4, global warming has some negative consequences for future hydropower projects and the impact of large dam hydropower projects. While preparing the long-term plan and its implementation, these consequences must be considered. If all of these constraints are considered, the development of renewable energy resources can help the nation to fight against the use of non-renewable energy resources.

5.2. Emphasis on electricity regularity and quality

Due to the fact that Nepal had an inadequate supply of energy, up to this point people focused all of their attention on its generation and distribution. However, in order to accomplish the goal of energy conversion that is anticipated from electricity, it is necessary to establish electricity as a service that is indispensable and to govern electricity's regularity and quality in an efficient manner. The reliability and quality of an electrical power system are the functions of several factors such as service availability, voltage fluctuations, system loss, reserve capacity, and forced load interruptions. Nepal faces many challenges to maintaining a reliable supply of electricity mainly because of uneven distribution of hydropower potential across the country, highly dependent on the power imported from India during the dry season, bottlenecking of transmission infrastructure, runoff river type hydropower dominated national grid, the weak distribution system, and low investment on the power quality. As per the NEA, the total system loss has reduced from 25.78% to around 15.38%, but still, there are many possibilities to get that value lowered. The integrated Nepalese power system (INPS) is not so large in size, but it has faced 44 partial blackouts in the fiscal year (FY) 2021–22 [35]. Recently, the total installed capacity of hydropower plants in the country exceeded the maximum electricity demand of the country however a large share of electricity demand is imported from India mostly during the dry season. It is making our national grid dependable on the Indian grid. Most of the hydropower plants installed are in the eastern and central parts of the country. Because of the limited capacity of the transmission line connecting the western part, severe voltage fluctuations and the compulsion to import electricity to that region still persist [35]. Nepal has just been moving to a reliable and quality supply of electricity after surpassing a long load-shedding situation. Capacitor bank installation projects, auto re-closure switch installation projects, automatic power factor controller installation projects, energy mix, and efficiency regulation concepts carried in these days are the proofs. Nepal recently doesn't suffer in the supply of sufficient electricity to meet the current demand because of the huge generation capacity added to the INPS recently and the electricity import-export contract with India, however, there is an appreciable interruption in the demand, as shown in Figs. 7 and 8. In terms of

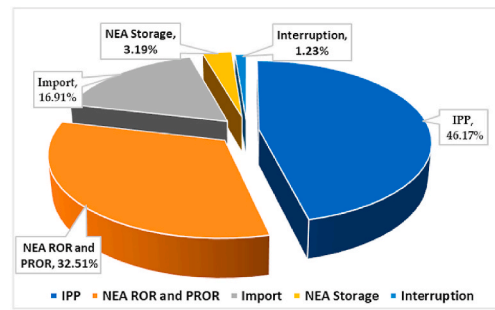


Fig. 8. Availability of energy (GW) in the FY 2021/22 (Data taken from Ref. [35]).

energy, the share of interruption is almost 1.23% of the total available energy. Based on the time at which interruptions are seen maximum, it can be said that it is mainly because of the system reliability issues caused by seasonal and atmospheric conditions, such as rainy and windy situations. People will only trust that the electricity supply which will be used at a fundamental level, if they receive a service that is dependable, consistent, and of high quality. For this reason, it appears vital to improving the dependability of the energy supply by implementing international quality and international service standards for the electricity supply. Despite the fact that institutions and commissions have been set up for the purpose of regulating electricity and services related to electricity, they are unable to function effectively. Because of this, it is important to improve their ability to organize and make them work the way they were meant to.

5.3. Regulation on quality, energy efficiency, and user safety of electrical equipment

Although the use of petroleum is being discouraged and the use of electrical equipment and tools is being encouraged in order to increase the amount of power used, there are no broad and clear regulations for the quality, energy efficiency, or safety of people who use that equipment. The desired effects have not been seen by regulations and regulatory bodies. Because of this, low-quality, expensive, and economically inefficient electrical appliances have been imported. This makes the user not been able to place full trust in the electrical equipment and tools, which is producing greater difficulties in terms of the increased usage of electricity and the displacement of petroleum. Also, a large number of electricity cause accidents have been reported each year [45]. It is very important to set policies in terms of parameters specified by international standards and practices to regulate the quality of supply, energy efficiency, and user safety-related issues. A few regulatory governmental institutions and departments like the electricity regulatory commission (ERC), the Nepal energy efficiency program (NEEP), and the energy efficiency and loss reduction department of NEA are recently established to maintain the quality and efficiency of the supply of electricity. However, their functions are not satisfactory and effective yet. Petroleum has been continuously used for a long time to satisfy people's fundamental needs like cooking, and transportation, therefore, the alternative energy which is expected to replace the former much be of very good quality, efficient, and user-friendly in terms of safety. So, it would also help to get rid of petroleum if the organization in charge of regulating power and electrical services had to come up with standards and policies related to this issue and make sure they were followed.

5.4. Electric vehicles and infrastructure

Up until now, the transportation industry has viewed electric vehicles as the wave of the future. There are a wide variety of potential applications for electric transport. But none of the possibilities are perfect in terms of the technical, economic, and environmental impacts they

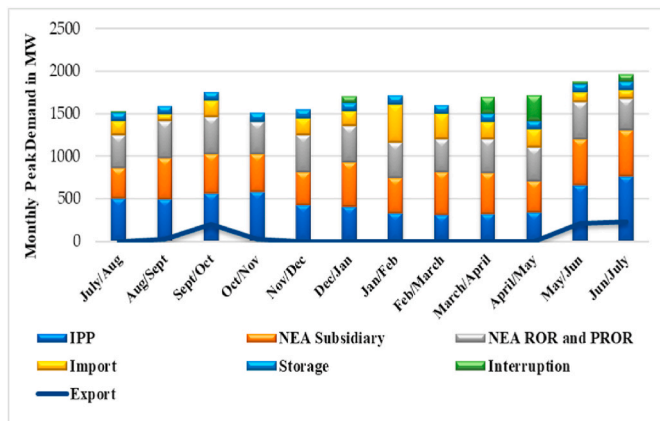


Fig. 7. Capacity balance (MW) in the FY 2021/22 (Data taken from Ref. [35]).

might have. Some applications have been seen to present a great number of technical challenges; some applications have been seen to not be suitable for Nepal from an economic standpoint; some applications have been seen to not be suitable from the perspective of the impact they will have on the environment. However, developing a new form of electric transport is not possible for us, we are obligated to select and develop the most appropriate technology for the requirements using various technologies that are already accessible. Because the number of personal automobiles is increasing dramatically in all nations, the transportation industry as a whole is dealing with a great deal of competition; thus, the infrastructure that supports transportation needs to be strengthened. In the realm of building, it is imperative that public and collective modes of transportation be given top billing and that the focus is shifted toward customer service. In the context of Nepal, the very first significant step in utilizing electricity in public transportation, after the trolley bus (not in use now), was to use a battery-powered three-wheelers vehicle known as Clean-Tempo during the mid-90s. It was so promoted that more than one hundred thousand such vehicles were imported in the single fiscal year 2015/16 [46], and is still considered very effective in local transportation. However, the import of electric vehicles has been seen as very affected by government policies, taxes, and subsidies. Despite the encouragement of the government to use electrically operated vehicles, the percentage of electric vehicles imported to the total number of vehicles imported was only around 5% in the fiscal year 2019/20 [46]. Nepal is importing two-wheelers (motorcycles, cycles mopeds), three-wheelers (e-rickshaw/tempo), and four-wheelers (cars, jeeps, work trucks, and others) vehicles powered by electricity noticeably in the last ten years. However, their numbers are not increasing in an expected way, as shown in Fig. 9. This Figure is constructed by taking information from the annual foreign trade statistics of Nepal [46]. Almost decades after the commercial use of electric vehicles, NEA recently completed its project of setting up its first 51 charging stations across the entire country as the first governmental step to develop infrastructure for battery-powered vehicles. Except for a few private sector-owned cable projects and a 33 km long diesel-electric train line, Nepal hasn't developed much infrastructure for electric transportation to help the petroleum displacement. At this time, although there are some issues with the usage of battery-powered vehicles, electric trains, ropeways, and trolleybuses without tracks are all acceptable for the transportation of passengers over vast distances [47]. When looking for an alternative to the transportation system that is currently in place in the city of Kathmandu, which serves as the capital, trolleybuses that do not include tracks appear to be a more viable option [48]. It is inevitable that new technologies will be developed due to the fact that the world is continually searching for technologies related to electric vehicles. As a result, the government should remain optimistic about the construction of sufficient electrical energy sources and infrastructure in order to accommodate these new technologies.

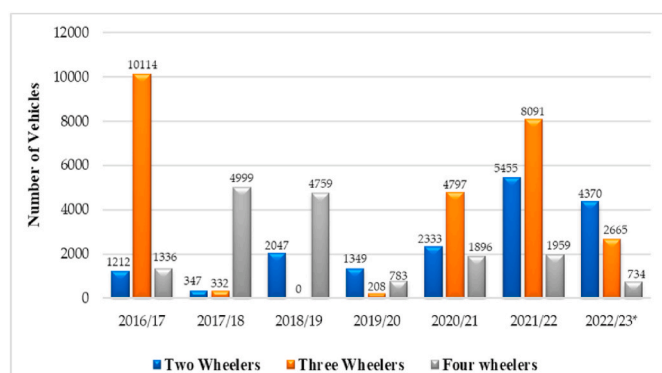


Fig. 9. Rise in the number of electric vehicles in Nepal.

5.5. Feasibility study of biofuel use and production

The portion of the total amount of renewable and clean energy (biofuel and electricity) utilized in the global transportation industry that is contributed by biofuel makes up approximately 90% of the total [49]. Despite the many benefits of using electricity, its application in the transportation industry is still much lower (about 10%) than was anticipated. This is owing to the limited capacity of batteries as well as the major issues that come with battery management. It has been determined that the utilization of biofuels, such as biodiesel and ethanol, is significant due to the fact that these fuels can be easily blended with the fossil fuel that is currently in use and does not require significant alterations in the motor vehicles that are powered by petroleum fuel. The United States, which is among the biggest reserves of petroleum in the world at the moment, is also the nation that produces and uses the most biofuels [50]. This makes it very evident that biofuel has its own unique significance and requirements. It is certain that biofuels will play an essential role in the process of converting the necessary energy from fossil fuels, despite the fact that it is difficult to manufacture biofuels in huge quantities instantly and supply the fuel needs of the globe with sole biofuels. Nepal still meets the major share of residential energy demand using conventional biomass, but the modernization of conventional bioenergy is a way ahead. As a result, it would appear to be important to do research in Nepal on the necessity, role, and application of biofuel production and energy conversion at a price that is affordable. As of now, there are no commercial applications of biofuels in transportation applications in Nepal, however, few initiatives and research regarding the possibilities in the use of biofuels can be found. The government of Nepal had already announced to mix of 10% ethanol in petrol in 2007 and a committee was formed to seek approaches to its implementation [51]. Nepal is an agricultural country and has abundant arable land considered favorable country for the cultivation of biofuel resources like palm oil, jatropha, soybean, and sunflower for biodiesel and corn, wheat, sugarcane, and potatoes for bio-petrol (ethanol). Alternative energy promotion center (AEPC), established for promoting clean energy resources, also taking a leading role in the implementation of the national biofuel program since the fiscal year 2008/09, which was focused on the production of biodiesel from jatropha [52]. It has been argued that cultivation of jatropha in only 10% of the area that is favorable for jatropha would be sufficient for the substitution of diesel [53]. Despite all this, it is unfortunate that Nepal hasn't been able to utilize its biofuel potential to limit and substitute the rapidly growing petroleum. It is an important advantage of biofuels that they can be mixed with existing petroleum fuels. So, intervention in policies and practices should be made as soon as possible to prioritize the use of biofuels in transportation for effective fuel transition.

5.6. Modern wood-burning stoves with low emissions

Over the last few years, there has been a significant rise in the consumption of LPG gas. In the past 10 years, there has been an almost threefold increase in the amount of LPG gas that has been imported [38]. Comparison in terms of equivalent energy shows that the LPG Nepal imports contribute to almost 50% of the total petroleum imported. Hence it requires much electricity for the displacement as compared to the diesel and petrol displacement. The majority of LPG imported is used in cooking and residential use. Despite the fact that approximately 94% of households have access to electricity, electric stoves have not yet established themselves as the most popular alternative. Wood-burning stoves are being phased out in favor of LPG gas stoves rather than electric stoves, particularly in more rural sections of the country, as a result of the unreliable nature of the country's electricity service. A clean cooking reformation plan that had been carried out in the past is still being implemented in many rural homes via the installation of less-smoke stoves that run on biomass and wood. Under this plan, many wood stoves are replaced by clean LPG stoves [54,55]. The anticipated

volume of use for electric stoves has decreased as a result of this kind of conversion. As a result, it is of the utmost importance to rapidly implement electric stoves in urban areas while simultaneously preventing the undesired conversion of stoves in rural areas. It is important to set up a reliable electricity system, and low-emission wood-burning stoves should be a top priority in this effort. Still, the majority of the population of Nepal resides in rural areas and uses solid firewood for cooking in a very ineffective conventional way. The major problems with this cooking are the indoor pollution caused and the deforestation because of the ineffective use of solid fuel wood. This can be solved simultaneously with low-emission wood-burning stoves with small efforts. Only about 35% of the total population has access to clean fuels and technologies for cooking as of 2020 [56]. Low-emission wood-burning stoves may not be the everlasting and sustainable alternative in reducing LPG but they may help in the journey of the cooking stove transition. Reliable electricity service in rural areas is still a challenge to the power utilities because of the geographic and dispersed location of villages. Thus, the role of low-emission wood-burning stoves comes into existence.

5.7. Pricing the oils based on the use

Because of the reliance on petroleum in every aspect of human lives, it is impossible to immediately replace this resource, moreover, it is the one that is being utilized the most. As a result, it must maintain strict control over the consumption of petroleum before moving to complete displacement. It is possible to make a positive distinction between basic, disciplined use, and luxurious and alternative use of petroleum and reduce the price for basic use, reward disciplined use and discourage the luxurious use of petroleum. This can be accomplished by setting appropriate prices and taxes for different categories. It can help to replace petroleum gradually in a very practical way, such as inefficient and luxurious use being replaced first, while promoting disciplined uses. The basic and inevitable uses are handled smoothly without affecting the lifestyle and creating a burden of fuel transition on the citizens. Using a model in a specific domain makes it possible to learn more about how hard it is to implement and how well it works.

5.8. Introduce petroleum displacement tax

When it comes to the deployment of petroleum displacement plans, Nepal faces the most difficulties and challenges, which is establishing the appropriate financial system. It is possible to arrange for the displacement tax at the selling price with the intention of assisting in the displacement of petroleum by the taxes resulting from the sale of petroleum itself. The amount of the displacement tax and concession can be changed within the indicated category, which will help with the controlling and displacement of petroleum in both direct and indirect ways. It is possible to articulate a policy that stipulates the total amount of money collected from the displacement tax shall be invested solely in the production of renewable energy and alternative forms of energy conversion.

6. Discussion and the way forward

India is the only source of fossil fuel for Nepal. India's petroleum reserves are barely sufficient for three years, based on the present demand; therefore, India is also dependent on other nations. Currently, petroleum is being extracted from its limited deposits, most of which are in developed, technologically advanced nations where crude oil is relatively easily accessible. The three nations that produce the most petroleum are the United States, Saudi Arabia, and Russia. The country with the highest reserves, Venezuela, has a poor rate of production. The world's total reserves of petroleum are predicted to last only 50 years if petroleum consumption keeps up at its current rate. Because of the increased cost of extraction and refinery, petroleum will continue to cost

more money in the global market with the depletion in the easily accessible reserves across the world that much is certain. Petroleum has a direct impact on the general population because it is mostly used in the transportation, industrial, and agricultural sectors. In such a circumstance, it is crucial for a nation like Nepal to discover a petroleum substitute as quickly as possible. Petroleum is anticipated to be replaced worldwide by modern biofuels and electricity generated from renewable sources.

Investment in renewable energy is rising in almost all nations. The majority of investments in renewable energy appear to come from nations with relatively small deposits of fossil fuels [57]. China and the nations of Europe are two examples of this. The displacement of petroleum has become a complex and big global issue. While several nations throughout the world have set the aim of totally replacing petroleum by 2050 or 2055, the current rate of development does not appear to be adequate. Nepal and many other developing nations will find it extremely difficult to expand renewable energy investments in order to fulfill the target within the allotted time frame. Even China, which in 2021 invested 35.2% of the global share in renewable and modern energy [57] and declared that it has enough money to replace fossil fuels, has acknowledged that the country's emissions from fossil fuel consumption may rise further until 2030. It means it wouldn't have control over the use of fossil fuels before 2030 and its progress is still poor to achieve the net zero emission target [58]. It is doubtful that Nepal will be able to replace fossil fuels anytime soon due to its excessive reliance on fossil fuels. Long-term strategies, initiatives, and developments in this area are crucial here. The percentage of renewable energy and biofuels in transportation, the main industry that uses petroleum, is only 10.2% as part of this initiative, which has been ongoing since 2005. Additionally, it appears that electricity only makes up less than 1% of the total. Renewable biofuels are currently assisting in the displacement of petroleum in the road transportation industry despite having a lower calorific value than petroleum. While there have only been limited attempts to replace petroleum in road transportation, no attempts have been seen for air transportation which also consumes a significant amount of petroleum. A newly developed hydrogen energy resource has been anticipated to phase out the gasoline from aviation. Numerous studies are being conducted on it. However, in Asia and Europe, renewable energy only makes up 15% and 22% of the overall primary energy supply [59]. Even if the globe gives renewable energy a high priority and pays close attention to environmental protection, there are still numerous obstacles to overcome. Electricity is now widely used around the world as a result of its effective multipurpose application, low leakage, simple control, and storage. Even at present, the production of electricity consumes around 44% of the world's energy. But still, coal is the most common resource for electricity production accounting for 36% of the total global electricity production. Therefore, the main concern forcing the world today is producing more electricity from renewable sources and fulfilling the demand.

Different nations are using different approaches to wean themselves off of non-renewable energy sources like petroleum. The trends in the energy supply, the fossil fuel reserves in the country, the availability of renewable energy sources, and the current political and economic situation of the country are all factors that have a direct impact on this. As a result, it's possible that Nepal's efforts to supplant its use of petroleum will be different from those of other countries. As Europe does not have major reserves of fossil fuels and because the nation's policy places a high focus on the utilization of renewable energy sources, the continent is currently in the lead when it comes to the displacement of petroleum. It is interesting to note that Singapore, which does not have a significant potential for renewable energy, is at the top of the World Energy Transition Index rankings for Asia. Because of its extensive use of low-carbon natural gas as an alternative to fossil fuel petroleum, as well as its policy of only purchasing power produced from renewable energy when importing electricity from other countries, Singapore has risen to the position of leader in Asia. India is the fifth largest country in the

world in terms of its coal reserves, so it uses coal to generate electricity, but it does not have abundant reserves of petroleum. As was just mentioned, nations that have limited fossil fuel sources tend to place a greater emphasis on developing energy from renewable energy resources. Because of this, despite the fact that Nepal adopts many similar policies impressed from India, the green energy policy that India implements, might not be appropriate for the countries like Nepal that do not have significant reserves of fossil fuels and generates all of their electricity through the use of renewable energy sources (primarily hydro). Instead, the policies that have been taken by Norway and Sweden in Europe may be ideal for Nepal to follow because these countries have significant potential for hydropower and consume fewer fossil fuels. Due to the requirement that all petroleum be imported, the ongoing price increase in the international market, and the fragile state of the economy, it is not possible to rapidly replace petroleum. Yet, delaying the displacement would not be a smart idea. Adopting a policy and a way of life that makes people less dependent on fossil fuel seems to be a key part of finding a good mid-way solution.

As discussed in the previous sections, most of the petroleum imported into Nepal is used in the residential and transportation sectors. In order to control and replace the use of petroleum, Nepal needs to focus on the strategies that deal with those sectors. This paper highlighted eight potential actions that can be implemented in the present situation of Nepal to gradually reduce and substitute fossil fuel consumption. Fig. 10 is a conceptual representation of some of the actions that can be implemented in Nepal in achieving the petroleum displacement goals. For instance, Nepal isn't able to replace traditional cooking stoves with modern electric stoves in rural areas because of the reliability of supply and power system infrastructure-related issues. However, low-emission wood-burning stoves could be a very suitable alternative for the successful cooking stove transition by limiting the further increase in the number of LPG stoves. Fuel transition is a long-time taking process and its pace depends on public support. Similarly, fuel transition in the transportation sector can be helped with the production of biofuels. The use of biofuels can help reduce petroleum consumption in transportation in an efficient and time-effective way. Furthermore, Nepal poses a favorable environment for the large-scale production of biofuel resources.

7. Conclusion

There are a number of concerns that are putting pressure on the world to reduce its reliance on fossil fuels and accelerate its transition toward the use of renewable and clean energy sources. Despite the fact that various projects are now being carried out in different areas of the globe in an attempt to identify alternatives to petroleum, it is crucial for Nepal to be prepared with separate long-term and short-term plans based on its conditions as soon as it is practicable. The application, importance, and displacement of petroleum in Nepal are discussed in this article. The investigation focuses on the present state of the nation. Along with a discussion of the many options that may be implemented to address the issues that have surfaced, a thorough study of Nepal's energy status has also been offered. This research aims to investigate the factors that have prompted the Nepalese government to think about reducing its dependency on petroleum and increasing its use of non-fossil fuel energy sources. There is also a thorough examination of the potential actions that may be taken to achieve the goal of replacing petroleum. The thorough analysis has led to the conclusion that the Nepalese government and policymakers need to take the potential of replacing petroleum products into consideration soon. This is a result of the fact that the usage of petroleum products has a big influence on the environment as well as the national economy. However, Nepal has a considerable amount of renewable energy resources, so if these are used, the country may get closer to being a wealthy and green one. However, one must first do the necessary preparation and research in order to be ready for long-term planning. The concepts will have both technical and

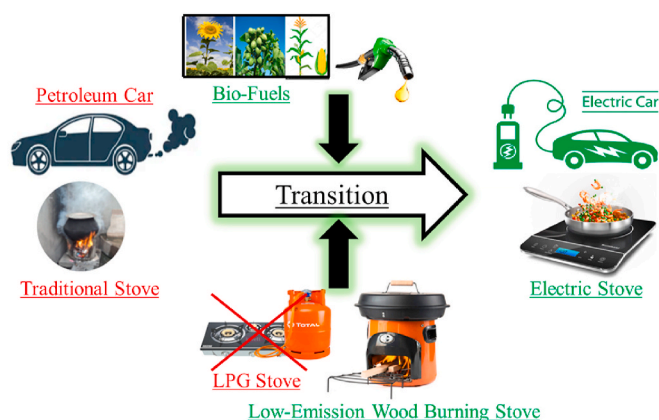


Fig. 10. Proposed fuel transition for Nepal.

environmental effects after being put into practice, both of which need to be taken into account. The analysis in this work does not give the influence of these factors the attention it deserves. It will be feasible in the future to do an analysis that considers the technical, economic, environmental, geographical, social, and political implications of the energy source in Nepal.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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