

CHAPTER 6

GENERAL CONCLUSIONS

As stated previously, the oil and energy sector, and more specifically transport, has not been synonymous of rapid change in the past. In fact, for decades, hardly any meaningful change took place as the automobile industry and oil giants, shared a married of convenience. However, the undergoing changes are unparalleled. There are many “unknowns” but undoubtedly such changes represent a paradigm shift with cataclysmic proportions.

Even before the Russian war on Ukraine, there was considerable uncertainty. This war has created an unpredictable geopolitical upheaval in the energy sector, exceedingly difficult to predict. One thing is sure, it will have huge economic, social, environmental and policy implications, with hundreds of billions of dollars at stake. Such changes represent both huge opportunities and also serious challenges and pitfalls.

In addition, there is even much greater challenges: climate change. The implications are enormous and beyond the scope of this book. The amount of data generated daily is such that it would be impossible to provide a reasonable representative account. One thing is sure, climate change is not something that may happen in the future, as many people might perceive it, it is already here and would not go away. It will get progressively worse if no fundamental actions are taken.

There have been many scenario predictions but hardly any of them turned out to be correct. Given the current situation, such predictions are even more uncertain. The energy sector is changing rapidly. Take, for example, the automobile of the future, it will be quite different in which decarbonization, environment and sustainable fuels will play a key role. Such changes represent an enormous challenge to both the automobile and oil industries e.g., technological, environmental, economic, political, and social.

While oil is not going away any time soon it will, progressively, be phased out over time. The Russia-Ukraine war might have two immediate impacts: i) the strengthening of fossil fuels in the short-term (2-3 years) because there is not any real alternative to fossil fuels; ii) speed up the implementation of renewable energy sources.

This is particularly the case of Western Europe whose external energy dependency is close to 90%, mostly fossil fuels. Europe consumes huge amount of energy and spend considerable financial resources. And for the first time, there is a growing political will to confront this uncomfortable reality. It is also a region with a huge human, technological, financial, and capital resources to make the transition to a sustainable energy scenario more realistic, if there is a political will to do so.

It can be stated, with certain degree of certainty, that many candidates are progressively emerging e.g., electricity, hydrogen, solar, biofuels (bioethanol, biodiesel). Therefore, the transport energy future will be dominated by a mixture of fuels in with no one playing the dominant role of oil. However, there is a danger that some countries may become too dependent on the electric car, which can lead major implications as stated.

The book main concern has been with the future of biofuels, with Brazil as the prime focus. Thus, within this context, what could be the potential role of biofuels in transport, and more specifically in Brazil? Biofuels have been around for many decades, and in particular in Brazil and USA, and to a lesser extent in other countries, hence they represent a lesser technological challenge by comparison, as it is a well proven technology and biofuel.

But as discussed in Chapter 1, the potential development of biofuels will be unequal within a global context. The Americas will continue to dominate, with Asian markets increasing their share, and with the African Continent (meaning Sub-Saharan countries), offering little future prospects, according to Maia (2022, Box 1.1). It is interesting to note that a region with considerable potential to expand biofuels, this seems unlikely in the near future due to a combination of factors e.g., social, cultural, economic.

Contrary, Görgens (see Box 1.2), is pinning up hope in advanced biofuels in conjunction with other RE (solar, hydrogen, electrification of the transport system, etc). This shows how unequally are biofuels development being perceived in different parts of the world.

Chapter 1 is a succinct global overview of current and future potential of biofuels in transport, subject to the uncertainties stated above. It provides a good amount of data and references for the interested reader to follow up. A point of caution regarding data. As already explained, the amount of data accumulated in so large, and changing so quickly, that often means little in the current form. Take for example, data of electric vehicle (EV), or battery technology which vary from one minute to the next. What is important is the general trend. Never in history have there been so many bright scientists and engineers, and dedicated resources, trying to find out new energy alternatives to fossil fuels.

This chapter also include a discussion of the pros and cons of biofuels and their historical perceptions. The pros and cons of biofuels have been heatedly debated, but on balance and if produced and used sustainably, the benefits far outweigh the negative impacts. Therefore, biofuels represent a considerable advantage over other emerging alternatives.

But biofuels are not excepted of negative impacts that limit their potential in many parts of the world, real or perceived. The main one being land competition with food production and the requirement of being environmentally sustainable. The “food versus fuels” dilemma, as stated, has been the object of heated debate for decades. The debate (e.g., see ROSILLO-CALLE, 2018) has been clouded by vested interest, bias, and lack of reliable scientific data. The “food versus fuel” debate needs to consider the intertwined nature of biofuels, land use, food production, food waste, animal feed production, diets, social habits, food distribution systems, policy, and so forth.

In fact, the FvF problem is an outdated, misleading, and increasingly discredited argument. Even in the EU where this argument has been a major political issue, now accept the positive contribution of biofuels to the environment and food security.¹

The biofuels industry needs to transform itself by moving away from using feed-stocks that compete directly with food production e.g., woody biomass and agroforestry residues, and explain to the wider public more successfully, as it has not been the case so far, and with robust data, that FvF as widely portrayed so far, lack fundamental scientific credibility.

The way FvF is perceived needs then to be overcome and buried. There is even a greater problem, often overlooked, and it is the unsustainability of food production. Chapter 1 also points out that no country is an island and hence what happens around the world will impact directly or indirectly in an individual country and its policies, and Brazil is not an exception, despite its unique position and historical experience, and natural advantages with biofuels.

Environment and climate change will be key drivers in any future energy scenario as already emphasized. This requires international agreement or some kind of consensus. But environmentalism is clouded with conflicting and contradictory vested interests. But as stated in the Introduction, when Homo Sapiens faces very serious problems, can find solutions above and over strong disagreements.

Thus, the future development of biofuels will be partly shaped by external factors. And this poses the question: *will Brazil use these advantages to promote biofuels in the future? Have biofuels a future in Brazil?* Answering these questions have been the aim of this book

1 See for example, David Carpintero short article: Food and Fuel for Europe – The Future of Renewable Ethanol, Ethanol Producer Magazine, 17 December 2022.

Chapter 2 deals with the historical developments of the ethanol fuel in Brazil. The history of ethanol fuel is fascinating, with many twists and turns. Ethanol fuel had had many supporters and detractors. Its origins go back to 1887 when Nikolas Otto used ethanol in his first engine. And in the USA, Gerald Ford also used ethanol in his T-Model car. In fact, Ford thought that in the future, “cars will be powered by ethanol”. In 1907 the USADA published a very interesting paper on *The Use of Alcohol and Gasoline in Farm Engines*. It was only when oil was discovered in large quantities in the USA that gasoline became the real alternative to ethanol.

Returning to Brazil, the reader interested in the history of fuel ethanol will know that it goes back as early as 1902. During 1920s many experiments were carried out, and as can be appreciated in the photo below (Figure 6.1), the use ethanol gasoline blend was a normal feature for automobile enthusiasts.



Figure 6.1 One of the first ethanol fuelled vehicles in Brazil, a Ford automobile, specially prepared at the Estação Experimental de Combustíveis e Minérios (today Instituto Nacional de Tecnologia-INT).

Source: INT (2022).

This chapter highlights how biofuels have evolved in Brazil through its various historical phases. It has identified the most salient features such as policy changes, technological achievements, regulations, major actors in the development of biofuels, agriculture, social, and environmental issues, as well as lessons learned (e.g., see also CORTEZ, 2016).²

It has been a long and arduous road, with many ups and downs. It is a rich history of failures and successes. A salient feature, perhaps from the eyes of many people in the 21st century, is lack of any environmental sustainability concern. But there was a school of thought at that time, whose core policy-making philosophy was economic development. This thinking considered that social development will trickle down as a

2 The interested reader on the development of biofuels in Brazil, should read PROALCOOL 40, 1975-2015. It is in Portuguese and is an excellent account of the main protagonists on the program.

result of improving living standards, and biofuels development reflects this reality. It has been a long road since environmental sustainability has been taken seriously.

Chapter 2 provides, therefore, a realistic overview of this historical process for a spectrum of readers.

Chapter 3 embraces all major aspects of the current situation of biofuels in Brazil. It is a detailed description of ethanol and biodiesel development, ranging from current status, opportunities and challenges facing this industry and agricultural implications. This is back up by robust data. It is worth restating that Brazil is currently the world largest user of RE, with 48.8% of all energy, primarily hydro and biofuels.

The chapter also includes an analysis on a more recent phenomenon, that is, the use of corn to produce ethanol. This is a significant development since sugarcane has been, historically, at the core of ethanol fuel production. The chapter discusses the pros and cons of this new feedstock that can have major implications in the future. Corn is a major crop in Brazil and its use as fuel will require new models and thinking on how to integrate sugarcane-corn production. It also has major implication for agriculture because corn is intercropped with soybean. It is a new emerging reality with significant economic, technological, and social implications. Corn-fuel is expanding rapidly because of its many advantages as explained in the chapter. It is, fundamentally, a replication based on the USA experience.

The expansion of biodiesel is not without its problems. It is a more recent story compared to ethanol fuel. Biodiesel is expanding quickly, and raising some concerns because, and although many other vegetables oil can be used, currently it uses primarily soyabean (c.68%) which has expanded very quickly causing considerable environmental concern as it is linked to deforestation of the Amazon. The deforestation of tropical forests affects both climate change and global warming, and Brazil is considered the most important emitter of GHG emissions from this source. However, reality is much more complex, and the main culprit has been extensive cattle-ranching.

The chapter looks also at other emerging potential markets for biofuels- aviation, maritime transport, and chemical uses.

Land use and biofuels are often seen as incompatible. However, in Brazil given its land mass area (850Mha), with huge amount of unused or underutilized land, the FvF has never been a serious issue, as explained in the chapter.

There are many challenges ahead. For example, the sugarcane ethanol sector currently faces a considerable challenge because of a combination of factors including:

- Expanding production. In the present model sugarcane ethanol is only viable if its economics are compensated and supplemented by sugar sales
- Electric mobility. This option has been presented as a “clean” solution, although the main issue is how electricity is produced. It can only be a partial answer.

- Domestic difficulties associated with relatively low engine efficiencies. Flex-fuel engines are no longer adequately responding the consumer needs.

As biofuels in Brazil do contribute significantly to mitigate GHG emissions, it is imperative to discuss new production models to satisfy the present needs, and to connect these modern biofuels with modern/modified engines. These solutions require mid and long-term policies involving not only Brazil but also international private enterprises and governments.

Chapter 3 is a good compendium of the present situation of biofuels in Brazil. It provides a considerable amount of data.

As discussed, throughout this book the energy sector is in turmoil. This situation, however, will differ considerably from country to country, depending on the level of energy dependency. Fortunately for Brazil it is one the countries with considerable energy self-sufficiency and in which RE plays already a major role. Its historical experience on RE, chiefly hydro and biofuels, puts the country on a solid footing.

But having a historical experience is not enough if this is not back up by scientific, human, and technological capability, and capital. The book has also stressed the fundamental R&DD required to overcome the challenges, and Chapter 4 focuses precisely on these issues by investigating alternative biofuel models and feedstocks. To survive, requires constant change, innovation, and adaptation. We live in a world driven by this continuous change, particularly scientific and technological, driving everything around us. It is an increasing challenge compounded by its complexity.

This chapter demonstrates that Brazil has considerable R&DD capacity and know-how to develop new feedstocks, and process technology, particularly from woody biomass. Significant R&DD has been underway for many years in universities, research institutions and industry. Many routes are being investigated and it is an invigorating research field. With the right policies and support, this area could advance rapidly. Although it is also clear that there is considerable room for improvement, to move away from current unsustainable economic, technological, and environmental models.

For example, a better management of cattle ranches can easily result in freeing considerable amount of land while being environmentally more friendly. The combined production of sugarcane-corn presents an excellent social, economic, and environmental benefits while making better use of existing natural resources. This means significant changes in land use models.

There are, therefore, realistic alternatives to current unsustainable production models, ranging from process technology to new sustainable feedstocks, to economic models that make better use of existing resources with considerable economic, social, and environmental benefits.

As stated in previous chapters, forecasting an energy future scenario is notoriously difficult and uncertain. We live in a world driving by complex and rapid technological, social, economic, and political forces. Technological innovations and betterment, influence consumer's preferences which in turn influence scientific and technological change. A world where mass data/information is available at your fingertips, is wonderful. But not without its dark side since data can easily be manipulated to serve particular interests.

Chapter 5 tries to foresee the future of biofuels in Brazil, within this constantly changing reality, from technological adaptations of engines and fuels to possible adoption of new fuels such as electric and hydrogen driven vehicles. In particular it tries to answer the following questions, specifically with regard to Brazil:

- The potential new role of biofuels in the transportation sector in a rapidly changing world energy scenario
- Assessed new emerging energy alternatives and their implications for biofuels,
- Examines potential conflicts and complementarity with biofuels of such new alternatives,
- New emerging market opportunities and challenges for biofuels.

Brazil is a unique case because of its well-developed biofuel programs (bioethanol and biodiesel) which has transcribed in considerable benefits e.g., technological, economic, and social. It is important to remember that many of the benefits from biofuel programs can be considered as "intangible". Brazilian economy and particular agriculture would not be the same without these programs.

Brazil could improve its already mixed energy matrix, with biofuels increasing their share while at the same time phasing out or reducing the contribution of fossil fuels. For example, enhancing the use of biofuels by introducing hybrid engine = ethanol + electricity, ethanol + hydrogen. The country has already in place most of the infrastructure and know-how. A few conclusions can be drawn from the Brazilian experience on sustainable biofuels:

- Biofuels have become an important instrument to energy security, GHG emissions reduction, and socio-economic activity in Brazil. Greater emphasis should be given in the 21st century to decrease fossil fuels dependence while enhancing the GHG emissions agenda.
- Biofuels can play an increasingly important role in the energy transition in Brazil since they provide the greatest potential for GHG emissions reduction than any other alternative
- The FvF problem so far failed to have any significant impact in Brazil; there is not a direct relationship between biofuels and food production. On the contrary, large scale biofuels production has helped to modernize the Brazilian

agribusiness sector. In any case, it is a chimera to think biofuel production would be given priority over food production. The FvF argument is misleading and outdated.

- Land use in Brazil needs to be improved. The major issue refers to pastureland, responsible for about 20%+ of all land in the country. If pastureland and cattle production is minimally improved, substantial amount of land could revert to food and biofuels production while improving biodiversity. Land use is a key issue to protect virgin forest such as the Amazon Forest and Pantanal.
- Efforts should be made by the private sector and Federal Government to make further progress on final use of biofuels. The present model of flex-fuel engines no longer satisfies present and future needs. Also, the proposed programs RENOVABIO and ROTA 2030 should be complemented with a new automotive model.
- Biofuels can also play an important role in the Brazilian international agenda involving trade, business, and cooperation particularly with medium and low-income countries.
- Brazil has the conditions to further promote biofuels, from an economic, social, technological, and environmental perspective. The question is, is there a political will?

FINAL THOUGHT

In the objectives we asked the following: *what could be the potential role of biofuels for transport in this emerging and mixed energy scenario, and more specifically in Brazil? What can possible be the new role of biofuels in the emerging energy paradigm? What lessons can be applied from its unique Brazilian historical experience? What lessons are there for other countries?*

This book has tried to answer such questions by carrying out a detailed analysis of biofuels in Brazil, ranging from historical developments, present and potential future directions.

We are aware that some sentences/paragraphs are repeated. This is to reinforce/emphasize certain specific aspects of the subject in question.

Based on the evidence so far, it is concluded that Brazil has all the necessary conditions (human, scientific, technological, economic, social) for biofuels to thrive and enhance their future, though partly conditioned by political considerations and prevailing international conditions.

The world has moved a long way since the first biofuels programs were setup. The world that gave birth to such initiatives has long go. At the present moment we are facing very serious challenges with surpass recent decades. To start with, and unlike decades ago, environmental sustainability and climate change cannot longer be ignored. On the contrary, these are key driving forces that need to be incorporated into the new reality of biofuels. We also need to overcome the FvF argument and replace it for the multi-products benefit.

The energy sector is going through a major paradigm shift whose outcome is difficult to predict. As we have seen throughout the book, a fundamental shift is ongoing in the way we produce and use energy, away from fossil fuels and in favour of RE. We are facing a world in which no transport fuel will dominate, as did oil. Again, the current energy challenges could move in both directions: i) increasing fossil fuels (at least in the few years), and ii) accelerate RE. This energy crisis is teaching us very important lessons, one of which is that we cannot go back to old habits. It could be the catalyst for a truly fundamental change.

The speed in which scientific and technological innovations are being introduced is overwhelming. This is opening up many new possibilities, though not without pitfalls. The combination of many of these factors are facilitating fundamental changes on consumers attitudes.

The future of biofuels in Brazil is bright but conditioned to changes demanded by society such environmental sustainability, climate change, adopting new scientific and technological innovations, and increasing energy efficiency. It is important the political elite understands such changes and potential benefits this will bring and introduce the corresponding policies.

We are witnessing a golden era of scientific and technological innovations, which are transforming our knowledge and understanding of the world around us. In fact, so much has been accomplished and so many accumulated advances have been made, be small, that they are breath-taking. Such changes are, in many ways, beyond our capacity to absorb them. And this situation is pushing to a very narrow focus, very specialised view, in detriment of the wider reality, even for the scientific community. Take communications, for example. Do you remember when you sent a letter to your girlfriend and waited for days or weeks to have a reply? In just a few decades, to contact your girlfriend, or business partner on the other side of the world, takes just a few seconds!!

Homo Sapiens are the wonder of the world, but at the same time a scorn of the universe. In just a few centuries humans have achieved incredibly unimageable things.... The space station circles our planet, allowing to better understand of our fragile Earth; the James West telescope has gone past the confines of our known universe.... An interminable list of great achievements... Homo Sapiens is capable of sublime incredible actions.... !!

At yet, Homo Sapiens are at the same time the scorn of the earth and perhaps of our known universe. Beyond the wonderful achievements there is a dark side. Look

around you, plagued by misery, inequality, brutality, hunger, violence... Russia war against Ukraine has shown, once again, the dark side and brutality of the human animal. The human animal can achieve so many wonderful things but cannot know itself, who are we, where we are going, what is our purpose...!

Homo Sapiens so grandiose and yet so miniscule!

We live in a world full of contradictions!!

Dear reader, we have come to the end of this exciting journey. It is hoped we have succeeded in providing you with a better understanding of biofuels, specifically with regard to Brazil, past, present, and future.

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