Introduction

This book deals with one aspect of a frightening situation. It talks about having a problem. But it is not the problem that is really scary; even children understand that problems often have solutions. It is rather that odd feeling that a child gets when it is clear that no one is in charge; that no one seems prepared to become seized of an issue, deploy the resources, and make the decisions. That kind of situation is unnerving indeed. As adults we know that we must either take charge of problems ourselves or do what we can to bring others together and start sorting out who can do what. There is some fear that the ‘adults’ are missing from the tableau. Our title, *Will Sustainability Fly?* is intended to admit of an open question rather than introduce its closure. But it seemed better than ‘Where Are the Adults?’ There certainly is an element of frustration in addressing such a question and writing a book like this, though. We do not have a book on how to solve the problem that I will describe. Rather, this book presents a deliberation on how to go about writing that other one. Here, the intention is to talk to those who have anything to do with commercial flight. The long list includes those who work in the industry, serve it, study it, or—and this is the part that brings in almost everyone else—those who use it, or would like to. What can be read here should interest anyone, and it is intended to be one small part of that exercise of asking people to think about who can do what. It will be about the way the sustainability challenge that we all face in other spheres makes itself particularly apparent in aviation. Because air travel is important to us, almost no matter who we are or what we do. And, as it turns out, this challenge of bringing sustainability to aviation, while evidently daunting, is probably the best shot that we all have in making a big, important, infrastructural, energy-intensive activity into something that stops harming our planet and its societies. This struggle could help us all learn a lot about the larger job. If we care, much of what is in these pages is very good news. But just like winning a prize, it is only good news if we follow through and cash the cheque. We will examine things from the perspective of taking what we have and actually *using* it.

In a cautionary vein, though, establishing a balance between our capacities for biting and chewing is also important. Understanding that the problem about which we speak is huge, what is written here is limited in scope to one particular part of it: commercial aviation’s quest for sustainable flight energy—fuel. The bigger problem can be described as that of sorting out how human activity can continue in the world without wrecking it. Our smaller bit (in that context) is: ‘What do we put in airplanes to keep them flying? How would that happen?’ I find the topic thrilling. It is interesting on its own narrow merits but, even more interesting, it reveals so much about the bigger one. ‘Will sustainability fly?’ is not merely a word trick to reveal that we need to think about whether flying
can be done in a non-destructive way. Rather, the resulting inquiry also uncovers so much about the more important question. In that respect, ‘Will sustainability fly?’ can be read as asking if ‘Sustainability’ is something that makes sense—in flying or anything else. We cannot know about flying’s part unless we know what it is supposed to be part of. In broad strokes, we need to know how the topics of sustainability and fuel link to one another.

Fuel is an interesting thing. One way that we distinguish fuels is on the basis of where and how we get them: Do we pick them up, burn them, and then wait for more of a similar kind to grow? Or do we dig them from a fixed supply beneath the ground? Until a few decades ago we hardly made that distinction at all. Fuel was fuel and we only really needed to think about effort and expense in its procurement. Now we know that this distinction is critical. There are other ideas too. Fuel is not energy, it is a substance that contains energy—in most cases, chemical energy. One way of viewing the puzzle is figuring out if there is a way to capture different kinds of available energy and put it into the manufacture of a substance that we can use for fuel. So we are really talking about a sustainable source of energy for fuel. In other areas of human activity we can exploit energy directly. But while airplanes may come with batteries in the future, it will not be soon. Airplanes need portable, liquid fuel.

There are technical solutions to this largest component of commercial aviation’s sustainability gap, but those solutions sometimes languish unnecessarily in laboratories and in portfolios of business cases, gathering dust. Here we will address our way forward in terms of how to get those technical solutions in place. Right now, we do not know that, nor what we should do to help make it happen.

Socrates gave us what we all now consider a common insight about the nature of questions: ‘Understanding a question is half an answer.’ What is presented here is information about a challenge. It is true that there are ideas and even suggestions sometimes too. But even these are proffered not as answers, but as ways of stimulating deeper thought about where we are and what we lack. What I would like to do is to help all of those who care to better understand what we are up against. This is a travel guide; our journey here is to begin to appreciate the nature of the job, its size, the reasons that it exists, the things that offer themselves as capable of addressing it, and what we have to do to make the necessary actions possible.

Why is fuel the thing? There is a lot more to aviation than burning fuel. True. But jet fuel is the single largest material input for powered flight. Each commercial airplane—whether relatively small and costing tens of millions of dollars, or large, and costing hundreds of millions—will burn through its own purchase price, many times, in fuel.

Thinking and motive in considering alternative sources of flight energy has been an evolution. There was a time, of course, when sustainability was not part of any equation that we acknowledged. In the past, the focus of alternative fuel was principally directed toward the problems of price stability and security of fuel supply. These remain key issues. But the industry seems to accept that new
sources of fuel must perform better on criteria of sustainability. So, in the end, this book was written for reasons that are somewhat different from those that led to its conception. It has migrated some distance from being a simpler book about why and how an industry must change the source of its most important energy supply to a broader look at the nature and important implications of that change.

Several years ago, I was closing in on the end of a flying career that had me piloting commercial aircraft all over the world. But I was interested in environmental matters and stunned by the size and complexity of the problem that seemed to be arising around the matter of global warming. I was learning more about climate, so I knew that if the stories were true, aviation must constitute an enormous part of the greenhouse gas (GHG) emissions profile of people who spend time aboard airplanes, and that would include (‘This is your captain speaking’) me. Where does all this fuel come from, and exactly what is the effect of burning it? Everything about the business has effects: building the aircraft, powering the infrastructure. But my attention was captured by the fuel question. I became very interested in what (if anything) my industry was doing to address it.

I acknowledge that my initial interest was too narrowly environmental and, even more narrowly, about GHG emissions from the act of flying. Lots of people who end up interested in the larger ramifications start out thinking that way: about the environment. But when we think about a better world and a more benign presence for humanity in it, the discussion is now usually framed in terms much broader than environmental. We now routinely resort to that notable word ‘sustainability’. Where did the matter of jet fuel lie in that regard? And, sure, maybe a different kind of fuel might allow aviation to have a lower impact on the environment, and in that way such a fuel would help flying to be more sustainable. But what of the implications (environmental and other) of producing such fuel itself? And how should our contemplation of all of these things be framed?

That gave rise to another more fundamental question: what exactly do we mean by ‘sustainability’? After a lot of reading, I discovered—as others have as well—that our understanding and agreement upon its nature and meaning is not entirely settled. The term is employed in so many ways that it has been rendered mere noise in many people’s hearing. The book is about a number of things, but the most important part of introducing the larger theme is to be explicit about how a discussion of the nature and understanding of sustainability in an industry context constitutes the root and core of everything that we must consider and accomplish.

It is an odd word when we use it in the current popular application that concerns the viability of the human project. There are certainly no easy substitutions for it. Still, in other respects, it is ordinary. The *Oxford English Dictionary* features meanings that relate to whether something can be perpetuated, supported and endured. Then there are ways of looking at those three characteristics not only in the physical sense but also in terms of justice and fairness. So we know what the word means: the same thing it has meant for centuries. It can be argued that when people ask what ‘sustainability’ *means* in current application, what they often really seem to be asking about is not definition but rather implication. If we ask,
‘What does it mean to fail this examination?’ we are asking about consequences. ‘Failure’ certainly means that we got less than the minimum passing grade, but what we actually want to know is ‘What happens now, as a result of this failure?’ So asking, ‘What does sustainability mean?’ could be, ‘What happens if we do what we must to make the human project and its component bits supportable, endurable, and perpetuable?’ or ‘What has to happen to arrive at that desired result?’ We are asking about conditions and consequences. It is time that we realized that the answers to those questions are simple in essence and complicated in application. The number of considerations is very large, and they affect one another.

And an odd metamorphosis has occurred as a result of our unrelenting use of this old word, sustainability, in the current global sense: We have so continually had reason to take recourse to it that the fact of its dual reference—to both physical and moral realms—has meant that we have not only started to weave them together but to understand (finally) that they must both be part of one fabric. So those of us who entered the subject with only the environment in mind have had to learn that the justice component must come with it or the environment cannot be saved—and why that is. As a planetary society, we are learning that perpetuating, supporting, and enduring in physical terms and terms of justice are all part of one, integrated whole.

We have all heard a popular formulation of sustainability as environment, society, and economics. That can seem arbitrary. Why these three things? Why not more? Why not fewer? But we are arriving at the relevant understanding of those questions. Society is us, and what we mean to ourselves and to each other; the environment is our physical milieu and our material support, creating, together, a very intricate dynamic. Economics is the way that we communicate value in that dynamic. If we do not understand each of the three factors in each of the others’ terms, we are distorting our perception. That has a bearing on how we act within the dynamic, and it can create problems.

But an effort to make sustainability relevant and real in a particular part of the world’s environmental, social, and economic milieu is not practical unless we understand the term in a consistent way. The only way that our understanding can be consistent is if sustainability is seen as comprehensively as possible; we cannot leave anything out. If we do, someone will disagree, and so they should.

That is a complex way of looking at something that some of us thought was simpler. Does anyone accept such a complicated approach? Thankfully, there are a great number of people and organizations that are well embarked and under way in making sustainability real and concrete for aviation. We must parse it, study it, examine it, and find the ways of putting it all together. That is what constitutes the efforts of those who are making the largest and most comprehensive understanding of the term as a real and assessable quality.

We preoccupy ourselves with definitions. When Einstein gave us *Relativity, the Special and the General Theory* (Einstein 1920), he didn’t create ‘relativity’ as a new word with a new definition. And ‘relativity’ still means what it has always meant. Anyway it wasn’t really a theory of ‘relativity’ itself, it was a theory about
certain things that he hypothesized were actually relative to each other. Perhaps it should have been advanced as the ‘theory of the relativity of mass, energy, time, and space.’ I do not know. But in any case, he was just using an existing word whose meaning coincided with his ideas. Likewise, we do not need a new definition of sustainability; we already have one (many). We need a theory of how certain things can be understood in terms of whether they can be sustained. We know what ‘sustain’ means. When we say ‘relativity’ now, the context often lets us know that we are talking about Einstein’s concepts. Likewise, ‘sustainability’ has become a bit of shorthand for a larger subject: Is human existence sustainable? What about component activities? How? In what form? Whether and how human existence and action can continue—whether they are sustainable, in the plain meaning— is still exactly what we want to figure out. I did not encounter any Einsteins in reading about and discussing sustainability. But I think that we should recognize the need to see how (what we are calling) sustainability might work and not just argue about what it means.

It is fair to ask why an aviation book seems to preoccupy itself with sustainability. Many readers may expect aviation itself to be the most important topic. The only answer that makes sense is that, regardless of anyone’s most prominent interest (aviation, manufacturing, agriculture, or anything else), sustainability is the larger subject. Anyone picking up a book entitled Can I Be Healthy? will be principally concerned with the ‘I’. But such a book will talk about what health is, and how to achieve and maintain it; ‘I’ will learn about health and understand what to do to adapt my actions to the pursuit and incorporation of health. That is what we are doing here.

But in some ways, the whole discussion has become much more complicated than it needs to be. When so many people think about so many different aspects of what we face in ways that are not necessarily consistent at all, it can get confusing. It started to seem to me that bringing the aviation fuel question to the sustainability context was like trying to jump on a train that was not only in motion but also still under construction; just not possible. I began to think that it was necessary to stop the train and try and get a version of it built in a way that would make sense to me, the reader, the aviation industry, and anyone else who cared to read. So now the book is about sustainability and whether aviation’s flight energy needs can be met in a way that conforms with our discoveries about its exigencies. The effort has been to change our understanding of sustainability from a shape-shifting chimera to an idea that should make sense to everyone who currently uses the word in different ways, and then to take on the question of whether we can bring this complex quality to the process of securing flight energy.

Whether one is a pilot or passenger, it gets personal. The experience of flying an Airbus 340-500 from Toronto and over the North Pole to Hong Kong, for example, involved the routine consumption of well over a hundred tonnes of jet fuel—

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1 A tonne (metric ton) is 1000 kilograms, or 2200 pounds. A North American ton (short ton) is 2000 pounds.
much more than would fill the average backyard swimming pool. Where does it all come from? Currently, jet fuel is sourced almost entirely from petroleum oil. (I say ‘almost’ because the first tentative steps to bring lower-carbon fuels into flight use have already begun.) Even in the larger scheme of things, that is a big deal, and it cannot continue. That is our particular job.

But aviation alternative fuels is a revelatory example of the complex challenges faced by the larger world, and it is my hope that we can begin to understand that a simplistic approach to the question of sustainability will produce a weak result or even make the situation worse. While acknowledging this caution, the main message here is that we can make things better—and we need to. Perhaps the way that aviation understands and pursues the goal of sustainability will help others.

One thing that makes aviation a wonderful entry point to the larger discussion is the relative absence of issues of national vested interest. While national interest always plays a prominent role, the question of aviation’s sustainability is slightly less wrapped up in the matter of advance or decline of specific countries than other industries tend to be. All countries use air travel, and it supports all economic activity. Air travel is important to everyone, and while it may be more important to some countries than others, we do not see that to the same extent as with many other parts of world commerce. And while we will see that air travel is a relatively small contributor to atmospheric carbon dioxide (CO₂), it is a big user of fossil fuel on a unit basis, so it is a great place to try to make headway.

Another reason to reflect on aviation’s status as a prime candidate for emissions-reduction initiatives is the attention that it draws. Air travel has a remarkably high profile. It elicits comment out of proportion to its environmental impact. While most CO₂ production in the developed world comes from burning fuels to do other things (heating, cooling, and power to run our buildings, machines and vehicles), producing cement (buildings and roads), and producing food (agricultural machinery, fertilizers, deforestation) (Le Quéré et al. 2013), seeing that one large aircraft overhead on its way to the other side of the planet seems a particularly profligate bit of environmental abuse. As a consequence, there will be mounting pressure to impose sanctions against air travel emissions. The industry will hope that those policies come with support for the sector’s attempts to improve. Otherwise, costly measures to penalize emissions may eat up the cash required for the development of technologies that could achieve the goal of reducing them. Aviation has been making a long and expensive effort to improve fuel efficiency (Penner et al. 1999, Intergovernmental Panel on Climate Change 2014) and although this effort continues, the sector will certainly want help in making the further order-of-magnitude improvements that will now be required.

Some of the important actions in this regard may have less to do with how air transport is accomplished and more to do with how much of it is. We have known for a long time now that reducing global warming will be a long, complex task—perhaps involving transportation mode shifts and a number of other things. Before anything else, we must acknowledge the need to grab the low-hanging fruit. Current strategies and policies are explored in Chapter 8, Transport, of
Climate Change 2014: Mitigation of Climate Change (Intergovernmental Panel on Climate Change 2014) and they include shifts to other modes of transportation and communication. However, we still need airplanes. How can we make them less damaging to the environment in terms of GHG emissions but also in other respects? Confronting the reality that aviation is not disappearing at any time soon, we start to wrestle with the question of how its impact might be lessened. Efficiency? Yes—absolutely. But it is hard to make flying more efficient—some of our most talented engineers have been working on just that for over a hundred years. While there is some substantial room for advancement in aircraft and engine design and in airspace management, nothing offers the revolutionary improvement in emissions reduction that environmental considerations must ultimately demand.

A new kind of airplane? That will probably come. But the start of a complete alteration of aviation’s energy regime is at least a generation away. A new kind of aircraft might be fueled, just for example, by liquid hydrogen produced using, say, renewable sources of electricity. But such changes are not envisaged at all in the transport trajectories to 2050 assumed by the International Energy Agency (International Energy Agency 2012). And even if we could introduce a new sort of aircraft technology tomorrow, it could not be built up to numbers sufficient to replace the current fleet for many years. So aircraft like the ones we have now will be around for a long, long time; what can we feed them?

We have to figure out new ways of getting the same fuel for them, but without continuing our dependence on fossil petroleum. This is the part of the discussion that is so encouraging. Science presents a few avenues; a prominent one involves converting biomass to jet fuel. Admittedly, many people will be startled to think that the aviation industry would consider trying to survive in a non-carbon world by resorting to things like biofuels. We are all aware of some biofuel experiences (notably corn ethanol) that have resulted in a certain amount of failure and disappointment. The fact that using corn ethanol as a substitute for gasoline so marginally reduces GHG emissions (if at all) has left the impression that biofuels cannot help. Clearly, if biofuel is part of the solution, it cannot be the kind that we have already seen, and we cannot make assessments about its sustainability the same way that we have in the past either. That is true. But we will see that this fact is also well recognized by those in the aviation and fuel industries, and that recognition is itself encouraging.

Then again, anyone familiar with the air industry might wonder how biofuels or anything else can be substituted for a specific kerosene hydrocarbon blend that airplanes, each constituting an investment of perhaps hundreds of millions of dollars, have been carefully designed to burn exclusively. To answer that question, techniques have been developed to turn various types of biomass into ‘paraffinic kerosene’ indistinguishable from the main component of conventional jet fuel. This is important because it is true (in practical terms) that commercial jet aircraft can only burn current types of jet fuel. Replacements do not take the form of a ‘substitute’—say, vegetable oil—but rather a ‘drop-in’ product that is just like regular old jet fuel. It might start off as vegetable oil, but means have
been developed to turn it into the appropriate hydrocarbon. Blends of up to 50 percent synthetic biojet fuel are currently in use on a very limited basis (Lane 2012). So a lot of the technology is now increasingly well understood—although it is constantly evolving, broadening, and improving. In fact, some of the most interesting research is into sustainable alternative fuels that are not necessarily biofuels at all. The current challenge is to scale up production, processing, and distribution infrastructure, and to fund the development of even better fuel technologies.

But the question about the very viability of the whole concept of renewable fuels is more interesting: can any of this be accomplished in a way that is really environmentally useful? Fortunately the answer seems to be, Yes—if we are careful. And the air industry seems well aware of the care that will have to be taken because there will be a great deal of scorn if alternative aviation fuels provide only marginal advantage in reducing GHG emissions, or if they bring about other new types of environmental degradation.

So, perhaps, it can get done. Right away? No. And that fact is at the center of the debate. Not the technology debate, the policy debate. No matter how much more quickly we would like to change, there are also good reasons why it will not be done without an incremental approach. Some of the best potential fuel technologies are the furthest away from deployment, and in trying to decide on alternative fuel options, major players must address many factors having to do with that relative readiness. The best solutions to the problem will not necessarily be the first ones deployed. And again—very importantly—we shouldn’t think that GHG emission is the only consideration here: the air industry has embarked on this pursuit of sustainable fuel with the understanding that invocation of the word ‘sustainable’ brings a more comprehensive onus than was borne by the supporters of renewable biofuels back in the 1980s.

All of this will be hard work. But it cannot be allowed to daunt us. We have to understand that the initial moves in the direction of sustainable fuels will be tentative, and will not satisfy the ultimate emissions reductions and sustainability goals that the industry must set. Sustainable aviation will be slow to get off the ground (smile). So a first realization is that there must be some room for evolution of understanding and effect. But getting started and speeding up are critical.

There will be challenges. The ‘food for fuel’ question is a huge part of the sustainability discussions and will not disappear. Many people will argue quite reasonably that using land for fuel production is never all right if people are starving. Others will say that as long as the land and other resources are not being used to produce food right now anyway, it does not really matter. How will our policies and our ways of assessing sustainability react?

And speaking of policy, another thing that the book explores is the historical policy context within which aviation commerce, on the one hand, and global GHG emissions, on the other, have been discussed. Policy on sustainable fuel may be a fairly new area of interest, but we do have other policies relating to how commercial aviation works and how emissions should be regarded. We will see
how important principles such as the equal and non-discriminatory treatment of air carriers as a consequence of discussions at the Chicago Convention in 1944 compete with the United Nations Framework Convention on Climate Change (UNFCCC) principles of Common But Differentiated Responsibilities (CBDR) for states, described 50 years later. Tricky stuff.

Much of the discussion about aviation and emissions at the international level now is about reducing emissions through charges or, alternatively, accounting for them through offsets. Obviously, in the best outcome, carbon charges and restrictions become irrelevant. But carbon charges, or market-based measures (MBMs), may play a critical interim role in achieving our goals. If they are implemented, can that be done in a way that gains universal support?

And if we accept that international policy discussions can be complicated, who else can move things along? What about the airlines themselves? Can they be relied upon to undertake action unilaterally? Well, yes—to a degree. The brightest stars do seem to recognize the long-term importance of getting away from the fossil fuel track. A strong international institutional commitment to sustainable biofuels is now apparent in the industry, with air carrier representation groups like the International Air Transport Association (IATA) showing increasing policy support for and commitment to sustainable fuel (International Air Transport Association n.d.). But the particular degree of commitment that individual airlines are likely to demonstrate in securing supplies of more sustainable jet fuel depends on a few things.

The first is the strength of its balance sheet. While cost of fuel is an extremely important factor, currently about 30 percent of costs industry-wide (International Air Transport Association 2014), long-term strategy and a cash dedication to securing alternative fuel at some point in the future is not necessarily appreciated by some boards of directors and is not even in accord with the time frame which most carriers do contemplate when, for example, hedging fuel.

The second factor is an airline’s managers’ knowledge; if there is thinking ahead about alternative fuel sources, it is this group’s understanding of which resource and fuel processing technology might best serve its interests, and (again) in what time frame, that counts.

The third has to do with the ‘vision thing’: an airline’s leaders will reflect some particular blending of national, corporate, and individual level of imagination and creativity. Some Chief Executive Officers do get it. But the complete re-conceptualization of the industry’s fuel supply is, like the response to deregulation in the 1980s, an exercise in collective mind opening that most technocrats will find daunting, despite the industry association consensus on the need to move toward sustainable fuel. Concerns include environmental liabilities, security of supply, and stability of price as the most readily exploitable deposits of petroleum are played out amidst rising demand. So interest is high, but the individual actors in the market (potential fuel suppliers and individual airlines) are having a hard time moving the fuel agenda by themselves.
In the context of the foregoing, it is not a surprise that air carrier interest in alternative fuels has focused not only on the cheapest but also the most readily available options. But airlines’ focus on immediate benefit puts longest-term sustainability issues at risk. Policy must take a longer view. We need to assess, in a comprehensive way, not only the relative environmental but also the social aspects of the production of fuel. It is understandable (and even desirable) that individual companies would focus on something that offers an immediate, albeit limited, environmental benefit, but someone has to be looking farther down the road to see where we should be headed in the longer term and taking concrete action to make that happen. It is becoming routine to see press releases about an airline’s commitment to the alternative sources of fuel. Policy development bodies must recognize that there are key players in industry who recognize and accept that short-term solutions are of limited value but who (like the rest of us) lack that crystal ball.

Alternative fuels from renewable sources are being developed and some are starting to be commercialized. Some of these initiatives represent strides in progress toward levels of sustainability. This makes some people think that there really is no need to do anything. There is. The problem is pace of commercial development: insufficient numbers of projects reaching commercial viability at too slow a speed. What policy related to development of sustainable aviation fuels should look like is very much an open question at present, but some things are fairly clear, and this book will make a case in the following terms.

The first is that the ideas that stand to deliver fuel in the most sustainable manner at the lowest cost are currently just at the research horizon. While such ideas do attract investment capital; they do not enjoy nearly enough support to move at an appropriate speed into deployment and displacement of poorer options, while those options themselves climb the difficult hill of building commercial, infrastructural, economic, and political commitment. To address this we need significant support for research, development and deployment of new fuel energy technology.

Second is the need to provide commercial incentive. But if policy must encourage success, it must also be prepared to sanction failure. Commercial entities can be limited in perception; they see market value almost to the exclusion of other factors. The externalized costs of carbon emissions are certain to be ignored until they constitute an imposed negative commercial value. There is little doubt that we absolutely need to develop more comprehensive and linked carbon pricing mechanisms, and we need to do it expeditiously; failure to help our world economy see the need to move into a post-carbon phase is very much a detriment.

Third, since key players, such as airlines, are sometimes blinkered by inherent short-term focus on current cash flow, only the largest of our institutions are in a position to assess the infrastructural value to the economy of major (and initially expensive) technology shifts. Only government can have the economic and policy-generating weight to help develop these brand new technologies and then move them into the commercial sphere fast enough to create a relative advantage.
Introduction

Anything worthwhile that we do must result from frank and honest assessment of the demands of our economy. The marketplace will certainly play its role in bringing more wealth and prosperity to the world as long as the market has all of the information in terms of the real cost of doing the wrong thing.

Certain governments are reacting, and this discussion gets beyond one country and one mode of transportation; around the world there is burgeoning interest in biofuels for all sorts of different applications. Heavy, long-haul road transport will not be able to get away from liquid fuels any time soon; there is just a lot more energy per unit mass in liquid fuel than in batteries and hydrogen for fuel cells at present. However, the air industries are especially trapped by their absolute reliance not only on liquid fuel, but also on such a very particular liquid fuel. For that reason, some governments are starting to react. In the United States (US), where the military establishment is the largest single consumer of energy, it was a Defense Advanced Research Projects Agency (DARPA) grant that helped UOP, a Honeywell subsidiary, to develop biomass-processing technology that made transmutation of the mundane byproducts of life into high-quality hydrocarbon fuels, possible—something that geological processes had taken millions of years to accomplish in producing petroleum (Warwick 2007). That initiative took place several years ago, and the US military is now fostering commercialization through procurement initiatives. Other research spending on alternative fuels technology is continuing to grow in the developed world. Even in the less-developed world, there is substantial support for alternative fuels development. China is committed to progress in developing advanced biofuels (though there are some doubts that it will be able to reach its ambitious goals 2011–2015 due to insufficient supplies of feedstocks) (Riedel, Scott, and Junyang 2013). And while massive levels of spending in superpower economies is almost inevitable in any area, one only has to examine the level of sophistication in analysis going on elsewhere to see that other countries are unwilling to be left in the dust. The United Kingdom’s Commission on Climate Change is a good example; it publishes an annual summary of the air sector’s GHG emissions and energy needs (Committee on Climate Change 2013) and many other useful reports.

The biggest challenge will be to elaborate the meaning of sustainability in the context of alternative aviation fuel and to have a broad international commitment to understanding, measuring, and demanding comprehensive subscription to various elements of sustainability. This will be a difficult challenge, since each facet of the broader concept affects each country in a different way and they will fight for advantage. But if we are not able to come to agreement, the air sector will be burdened with the costs of expensive offsets or taxes.

To outline what you are about to read in a more ordered way, we start with a discussion of the extent of aviation GHG emissions. It is necessary to see what contribution the sector makes to the global GHG problem, critically, to gain a sense of the way that GHG emission is distributed among individuals. Then we examine the likely evolution of this picture.
Confronting the challenge, the book takes on the questions about how we can make progress in reducing aviation GHG. Efficiencies to be incorporated in aircraft design, operational practice, and airspace management are seen to be crucial, but not enough. We examine the factors that affect development of completely new aircraft technology and why we are (still and nevertheless) left with the need to continue with aircraft that are a lot like the ones that we have now.

We then talk about why current aircraft and the newer, improved designs of similar ones cannot be asked to burn something other than kerosene (paraffin). This all eventually yields to a key question: Is there any other way to produce kerosene jet fuel? It is possible; it is being done. We will explore many of the developments that are occurring in new fuel technology so that the reader has some sense of what is possible.

All of that brings us to the threshold of a deeper discussion. In order to set the scene, we provide background on an essential element of this project: policy. What policy have we developed over time that might have a bearing on our discussion about what should happen now? Established policy is not about new fuels. It is about how international aviation is commercially governed, on the one hand, and the limitation of GHG, on the other. At some point, those two things must operate together in a way that fosters solutions to the challenges that we face.

If we identify ‘sustainable, alternative sources of flight energy’ as the most important tool that will allow us to face our challenge, the most critical thing is to understand the task in a coherent, rational, and consistent way. That is why the discussion about the word sustainability and its current popular usages is so important, and such a large part of this book and all of the discourse that will attend any of the subject matter in whatever forum. Our inquiry into how we might ‘measure’ the sustainability of fuel will reveal even more insights into the developing consensus on what it means and how it operates. This is an encouraging part of our story.

The last part of the book undertakes an examination of how those things that are physically, socially, and economically necessary can become possible; how understanding and need can be turned into policy that will bring the current evolution toward sustainable fuel to a pace and in a way that will serve the needs of the industry and society in all parts of the planet.

Finally, we talk a little more specifically about what is actually happening and meet some of the people, organizations, and companies that are part of the change. Throughout the book, I have depended upon comment and input from a number of people who are active observers of or participants in the effort to move us toward commercial inevitability for truly sustainable liquid energy for flight.

A ‘Fasten Your Seatbelts’ caution is not out of order: our first chapter will describe the size of our task.