
Preface

So I said, let's calculate!

Fred Hoyle, 1987

Climate and energy issues are today almost omnipresent in the media. To no doubt, they are among the most important challenges of this century. The topic is incredibly vast. It involves history, astronomy, physics, chemistry, math... plus a huge amount of facts and data. As a consequence, solutions are often proposed which ignore a number of basics. Before curing people, medical doctors spend years learning about the human body. With respect to the climate/energy continuum, it is extremely tempting to act as a “doctor” who would not have studied medicine. To suggest treatments which disregard facts, or the physics involved, for example.

This is why this book can be viewed as a *conversation starter*. It is not solution-oriented. It is knowledge-oriented instead. It is the fruit of a 4-months course I have been giving in Spain, for the last 10 years. Four months are far too short to review everything one can know on these topics. Yet, it is long enough to understand the basics of the problem, acquire the physical basis of every energy source, and learn how to perform quick estimations and calculations regarding their potential. This book gives an easy access to understand important numbers and orders of magnitudes—for everyone. Based on understandable explanations, an emphasis can be put on fundamental numbers, when relevant. As David McKay puts it in *Sustainable Energy: Without the Hot Air*, “Numbers, not adjectives.”

According to a famous saying, “give a man a fish and you feed him for a day; teach a man to fish and you feed him for a lifetime.” As we will go through the different topics, we will not simply learn about the results of calculations others did. We will learn instead how to perform the calculations ourselves. The goal is to reach the point where you no longer say “they claim such and such,” but “I know such and such, because I understand how it works, and I can do the numbers by myself.” As a consequence, many calculations are outlined here. But don't be afraid. Besides Sect. 3.2 and Chap. 8, where the exponential function appears, the

text involves simple arithmetic. More technical pieces and further detailed information for the interested reader can additionally be found in the appendices.

It is important to recognize from the beginning that what we have here is more than a mere collection of disconnected chapters. As the title says, the energy/climate problem is a *continuum*, and it is very important to grasp how its components are intertwined. Such a high level of connection echoes in the flow of the book, which goes as follows:

- Chapter 1 explains where we stand energy wise, in broad strokes. Then, even before learning the basics, you need to know who to listen to, how to perform quick calculations for yourself, and a few physics basics. This is Chap. 2. You need to understand what the energy problem is: we rely on fossil fuels, which will run out (not now) and pollute (now). This is Chap. 3. Pollution is spurring climate change. To avoid considerable warming, we need to replace fossil fuels *now*. Climate science is thus treated in Chap. 4.

That is the first part of the book. Understanding the energy/climate problem.

- The second part then turns to solutions. Which options do we have? Storing energy or carbon could be one. Also engineering the whole planet. This is Chap. 5. Besides these options, some physical principles allow to list exhaustively every kind of alternatives to fossil fuels. We can review them, and assess their global potential. This is Chap. 6. Is there such thing as a perfect, risk free, wastes free, energy source? Probably not. This is Chap. 7. Gathering the numbers and making optimistic assumptions, what do we get for the next 300 years? This is Chap. 8.
- The last part of the book is about history. Why? Because once the magnitude of the challenge set before us is understood, it is natural to wonder if it ever happened in human history. Do we know of past civilizations which faced obstacles of their kind? The answer is yes, and learning about them can be a key part of the conversation starter. Indeed, fragility happens to be a common characteristic of human societies, as explained in Chap. 9. Some civilizations could not overcome their challenge. This is Chap. 10. Some could, may we follow their tracks. This is Chap. 11.

The reader will note a fair amount of references in the body of the text, not unlike scholarly literature. There are two reasons for such a choice. First, very few can be experts in every single topic covered. I thus thought it would be convenient to mention sources as they are evoked. The second reason is quite connected to the first: in order to go over all the necessary material in a reasonable amount of pages, each section must focus on the bare essentials. The desire to read further should then arise naturally and repeatedly. Here again, citing sources in the body of the text allows for an immediate access to more material.

This Book may also be Used as a Textbook...

As previously stated, this book is the fruit of a course. A 4 months, 60 h course. It can therefore be used as a textbook, and I do. A course on these topics is highly rewarding for students who find answers to their many questions, and for the professor as well, who finds motivated students eager to learn.

The course is directed to students in engineering with no advanced training in math or physics, but may also be suitable for early stage students in other science disciplines (such as physics, chemistry, geosciences, biology), or even for physics and science courses for non-scientists. The math involved does not go beyond simple arithmetic. The difficulty of the course is not technical. It rather lies in the large amount of information and notions to digest and put together.

If you choose to use this book as a textbook, you will need problems and solutions, exercises, and so on. Fortunately, the very nature of the topic makes it very easy to make them up “on the fly.” Here is a list of suggestions in this respect:

- The book contains more material than what can be taught in 4 months. It is straightforward to choose any calculation explained, and turn it into a problem.
- Some sections can also be turned into a problem. For example, Sect. 4.2 on the earth energy balance can be started like a quiz: the professor starts noticing the earth has been receiving 1.76×10^{17} J/s (see Eq. 4.1) for more than 4 billion years, and asks “where did all this energy go”? Students will start reviewing the available storage options, evaluate their capacity, and conclude alone that what comes in, must come out.
- Most of the calculations presented can be modified endlessly. For example, the evaluation of the amount of carbon emitted by the Spanish cars in Sect. 2.2 can straightforwardly be adapted to any country.
- Due to the exposure of the topic, media are a constant source of exercises. Take any news related to a brand new green energy project capable of providing current for n households, and have the students check the numbers by computing everything. I have designed many tests this way.
- Along the same line, many newspaper articles can enter an exam under the form of a text to comment.
- The climate science part can be the object of interesting debates between students. For example, Fig. 4.10 shows carbon emissions should start decreasing by now to avoid too strong a warming. Since OECD countries emit much more (per capita) than developing ones, which policies would you implement to cut global emissions in a *fair* way?
- The history part is also a great source of debates between students. For each of the four cases highlighted, we can ask: What can be learned? Which points do we have in common with these past civilizations? Which differences? Regarding Easter Island, for example (Sect. 10.2), this question from Jared Diamond can be asked to the students: “What were Easter Islanders saying as they cut down the last tree on their island?”. An interesting debate always follows.

- The toy model presented in Chap. 8 can easily be computed from an Excel spreadsheet for students to manipulate. Regarding Spain, a similar Excel file¹ has been prepared to let them design energetic scenarios under various constraints (no fossil, no nuclear, no more than x tons of carbon emitted per capita...). This file can quickly be adapted to any country.

May this book allow you to design the most exciting course on the topic.

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¹ It can be downloaded from extras.springer.com

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Lessons from Basic Science and History

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