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Thierry Lucidarme

Decarbonisation
From Industrial to Personal Uses

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We must, laughingly, instruct the youth…

Molière, L'Ecole des maris, I, 2 (v. 169-182)

Introduction

We sometimes decide to write the books we wanted to buy and that we simply couldn't find. This is the case for this one. It is difficult to say for yourself that your own book aims to be the most neutral synthesis possible. It is likely that the author has inherited or been influenced by some parts of his professional experience, sometimes carried out in both very carbon-free (renewable and nuclear) industries and sometimes helping to decarbonise some more carbon-intensive (oil and gas) industries. However this book reflects the only opinion of its author and has been written independently of any company or industry or lobby of any kind.

And yet everything seems to have already been said or written on the subject in one form or another. The angles chosen to approach the subject are sometimes militant, political, technocratic, moralising or fatalistic. As stated by the epigraph of this book by Molière: "*We must, laughingly, instruct the youth…*", it is a duty to inform any kind of curious reader (and not only the youth) in the way that the subject is exposed simply and comprehensively. Of course it is however not a laughable subject, granting the stakes for the future generations it represents, however we should also not reflect too much the weight of the constraints and the hard necessity of success at the risk, as Moliere would have said, to become inaudible and crush the reader under a too heavy load to carry.

The challenge is even probably one of the most difficult ever met by humanity, as for a big part, this humanity, at least the one who benefited from the fossil energy for almost two centuries now, owes the technical progresses and the associated comfort of the society realised in a very short timeframe, to the efficiency of the fossil energies. We all know that the energy which is contained in just one litre of gasoline -or 10 kWh- allows a one ton car to achieve 20 km in a small amount of time. Assuming that a trained biker can drag 20 kg over one hour maintaining a 200W power generation (it is half what a professional can do, but try it, this is challenging…) then 50 human bikers would be required to do the same. This small example shows the difficulty of replacing fossil energies at least for some of their usual applications.

IPCC reports,[1] which follow one another show the impact of human activities (and therefore the generation of greenhouse gases) on climate change and its bleak prospects. Thus, if we consider that the industrial revolution is the genesis of the exponential explosion of carbon dioxide in the atmosphere, it is estimated that the quantity of CO_2 has increased in 150 years from 280 ppm (0.028%) to 420 ppm (0 .04%). This represents a mass of 2000 GT of CO_2 emitted.[2] Still, according to the IPCC, if we want to limit the rise of the temperature below 1.5 degree before 2030, we need to reduce our emissions by 33% at this date.

In our personal, social or professional experience, we often believe we can distinguish two main types of thoughts in two categories of people.

Those who do not believe in the short term in a (global) political or technological solution that could be fast enough to quickly limit the damage.

Those who think that we can still control greenhouse gas emissions through relevant choices and substitute fossil fuels with a number of solutions that will still allow us to meet the challenges of population growth and their aspirations to continue to take advantage of the benefits of available and accessible energy. They understand that regarding decarbonation, there is not one single "killer Technology" but more a set of Technologies that can be deployed provided their costs will decrease to a certain point.

This book aimed more to those in the second category who wish to be able to make a kind of inventory and better understand the technological solutions that are available or will be, as well as the logic of implementing these solutions according to their degree of maturity.

By proceeding with a simple logic: Preventing is better than curing, we will detail the two main functions of decarbonisation:

- Produce less CO_2
- Use and Value what is inevitable to produce, that is to say, what cannot be prevented.

Then we will zoom in on each of these major functions to understand them and detail their effects. The subject of the book is above all the decarbonisation of industry. However, the industry is composed of various streams that can be more or less hard to decarbonise. Then, after presenting the technological principles of decarbonation applicable to many vertical industries, we will look more precisely at two very important domains in terms of impact to decarbonise: Transport and agriculture. Transport is hard to decarbonise as per definition, the variety of transport means is wide and the emissions are very diffuse. Agriculture is also diffuse and complex as the intensive use of the soil without care prevents the natural capacity of the soils to store the carbon and even more carbon is released in the atmosphere, therefore there could be trade off between the necessity of feeding a growing population and enabling the soils to be a carbon sink.

[1] (IPCC: Intergouvernemental Panel on Climate Change).

[2] (Ozkhan et al.).

The decarbonisation of certain daily personal uses will however be addressed as well, in particular in its individual mobility and heating functions, because these large-scale uses have a very significant impact on emissions from energy producers.

Finally, we will study the technique of direct capture of CO_2 in the atmosphere, which could be a last resort to reduce the concentration of CO_2 in the atmosphere from 400 ppm (current rate) to a much lower rate.

Therefore, we propose in the following somehow a progression from the most dense and punctual to the least dense and most diffuse, because we believe that the costs of decarbonisation solution deployment are inversely proportional to the density of carbon dioxide to be treated for a fixed quantity.

As always when it comes to energy, the question of orders of magnitude is key. We will try to underline the orders of magnitude to be kept in memory for each solution presented.

Contents

About the Author

Thierry Lucidarme has worked for many years in the field of energy and Technology. At EDF's R&D (Electricité de France), he was aiming to detect and promote Research and Innovation projects that could decarbonize other industries or collective and individual uses. He also led the ADNOC company (UAE) R&D decarbonation projects portfolio targeting the carbon neutrality target of the United Arab Emirates by 2050. He is now with b<>com, a Technology Research Institute aiming to develop more sustainable digital innovative projects.

Chapter 1
Emissions Need to Be Reduced

1.1 Global Warming

Physically, the mechanisms of global warming are well known. They are linked to the increase in greenhouse gases which lead the atmosphere to absorb part of the infrared radiation re-radiated by the earth from solar radiation. The absorption of this infrared radiation results in a rise in temperature near the earth's surface.

It is not the first time[1] that certain cities or certain countries are confronted with the devastating effects of pollution, since as early as 1272 the King of England Edwards the 1st had to ban coal fires in the city of London. During the episode of the great stench of 1858, emanating from human and industrial activities discharging pollutants into the Thames, the Chamber of Commerce had to stop its debates and carried out major sanitary projects. In the United States of America, in the middle of the last century, certain rivers flowing into the great lakes were so polluted that they caught fire spontaneously. The examples are legion, but it is only during the last fifty years (see Fig. 1.1) that the phenomena of greenhouse gas emissions have become global and have reached such a scale that their impact on the runaway of global warming has become demonstrable, if not obvious.

Created in 1988 and wanted by the G7, the IPCC brings together 195 States. It is charged to assess the reality, the causes and consequences of the ongoing climate change.

According to the IPCC, but who still doubts it, global warming is accelerating as evidenced by the curves below.[2] The figure in the left clearly shows that:

– The surface temperature has never been that high across the last 100000 years (the hottest period happened about 6500 years ago between the two last ice ages). The grey curve is reconstructed from paleoclimatic archives and the black one

[1] Quiggin [1, p. 201].

[2] GIEC changement climatique 2021, les bases scientifiques [2].

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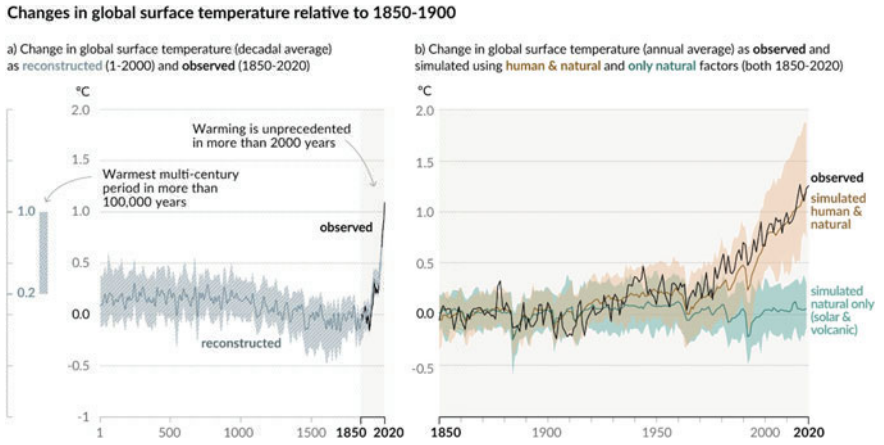

Fig. 1.1 Temperature evolution for the last 2000 years and over the last 150 years from Figure SPM.1 from IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New-York, NY, USA, pp. 3–32, https://doi.org/10.1017/9781009157896.001

is the ten-years average measurement curve across the last 150 years. The grey envelope of the curve is providing the tolerance of the reconstruction.

– The speed of the observed global warming is exponential following the industrial revolution.

The figure on the right side details the temperature rise since 1850 within its tolerance envelope, it simulates the hypothesis of a rise due to some natural causes only and one due to a cumulative effect between human activity and natural effect. Obviously, the second hypothesis matches the observations quite closely showing a strong probability of impact of human activity on the global temperature change.

The Paris agreements, during the COP 21 (Conference of Parties) set the maximum objectives for global warming at 2 °C by 2100.

This threshold of 2 °C corresponds to a value which, according to experts, if exceeded, would lead to a too high probability of extremely dangerous climate change. In terms of quantities, these two degrees could be obtained through the emission into the atmosphere of 2900 billion tonnes of CO_2eq, knowing that around 2000 billion have already been emitted, most of them in the last 50 years. In other words, humanity would have already consumed more than two-thirds of its carbon budget.

The IPCC[3] works on the basis of scenarios. The most optimistic takes global emissions of 40 GtTof CO_2 in 2015 as a starting point, and aims to obtain a reduction

[3] IPCC: Intergovernmental Panel on Climate Change [3].