Preface by the editors

The Norwegian refrigeration technology professor Gustav Lorentzen, † 1995, stated at an IIR meeting in Gent in 1993: "*In the present situation, when the CFCs and in a little longer perspective the HCFCs are being banned by international agreement, it does not seem very logical to try to replace them by another family of related halocarbons, the HFCs, equally foreign to nature.*"

Does it then make sense to replace hydrofluorocarbons (HFC), which are on a downward trend in many countries, with another family of related halocarbons? Certainly not! Unsaturated hydrofluorocarbons (uHFC) – marketed as hydrofluoroolefins (HFO) – are not likely to be a long-term solution either due to the influence of their atmospheric breakdown products on the regional environment.

Alternative solutions have been available for over 100 years, namely:

- Ammonia,
- Carbon dioxide,
- Hydrocarbons,
- Water and
- Air, or possibly N_2O mixed with CO_2 for low-temperature applications (< –50 °C / –58 °F).

They have all been found in nature for millions of years. Therefore, their emissions do not cause any unknown changes in nature, such as CFCs depleting the ozone layer or CFCs and HFCs contributing substantially to global warming or HFOs resulting in large amounts of trifluoroacetic acid (TFA).

It took over 40 years from the invention of chlorofluorocarbons (CFC) and hydrochlorofluorocarbons (HCFC) to the discovery of these synthetically produced substances' negative effect on the ozone layer and another 20 years before they were banned under the Montreal protocol. The Kigali Amendment to the Montreal Protocol signed on October 16, 2016, eventually will phase-out their replacement fluids, namely HFCs. Let us not wait such a long time to replace HFOs due to TFA formation in the atmosphere. Let us go back to the early beginning of refrigeration technology and re-use our old friends: natural refrigerants. Find out how to do it in this book!

The main reason for the decision to "phase down" HFCs under the Kigali Amendment is their high global warming potential (GWP). However, the direct contributions to global warming due to refrigerant emissions from refrigeration or air conditioning systems are often lower than the indirect contribution from CO_2 emissions from generating the electricity to operate the systems. Regardless of which refrigerant you want to use, the system must be more efficient in the future than its predecessor! Fortunately, many installations with natural refrigerants are very energy efficient due to the good thermodynamic properties of these refrigerants, as detailed in this book.

Yet another environmental aspect is the CO_2-equivalent emissions during production of the refrigerants. Natural refrigerants score by far better than HFCs and especially HFOs, resulting in one tenth or less of CO_2-equivalent emissions during their manufacturing process.

Each of the natural refrigerant solutions has pros and cons, and therefore different applications. Accordingly, in this book they are all covered in a separate chapter in which their preferred applications are described. For each natural refrigerant, we were able to enlist respective experts as authors. We thank all of them for their tremendous work writing this comprehensive book on natural refrigerants. A special thank you goes to Andy Pearson who extensively reviewed Chapters 1 to 4 with special emphasis on the ammonia chapter, which to some extent was based on his IIR Guide "Ammonia as Refrigerant" published by the International Institute of Refrigeration in 2008. We also thank Bernd Hansemann of VDE Verlag and Ilana Koegelenberg of ATMOsphere for their patience with us and their countless hours of work in making this book possible. Thank you to ATMOsphere and the whole team supporting this English version. As non-English native speakers we apologise for any inconvenience because of possible language errors.

A final thank you goes to you, the reader of our book. May you find some guidance in applying what we love most – NATURAL REFRIGERANTS.

Karlsruhe, Germany	Ludwigsburg, Germany	Assamstadt, Germany
Michael Kauffeld	Michael Eckert	Volker Siegismund

Introduction by ATMOsphere

The future is natural

Time and time again, the lack of suitable training materials in the natural refrigerant space has been cited as an excuse for slowed progress towards more sustainable HVAC&R solutions.

As an independent global market accelerator for natural refrigerants, ATMOsphere has been striving to remove barriers for the uptake of climate-neutral cooling systems for nearly two decades. That is why, when we first came across VDE VERLAG's German natural refrigerant textbook in 2019, we immediately saw an opportunity to also bring this expert knowledge to the global stage and address the training barrier.

The "*Natürliche Kältemittel – Anwendungen und Praxiserfahrungen*" German textbook ticks all the boxes, offering a comprehensive technical look at how to work with all natural refrigerants. By simply looking at the authors' list, it was clear that the textbook was the resource we had been waiting for.

After interviewing Professor Michael Kauffeld, who initially came up with the idea for the original textbook, I became even more convinced that this was something that could benefit a much wider audience, not just the German-speaking industry. Professor Kauffeld was kind enough to put me in touch with the publisher of the book, Bernd Hansemann of VDE Verlag, who immediately saw the potential of an English translation as well.

It would be safe to say that none of the parties involved (and there were many) had any idea of the sheer complexity of the project we had taken on. It was a pre-COVID world and we were optimistic that things would progress quickly with the translation and republishing in English. But things were a bit more complex than that. The volume of the book and the highly technical nature of the material meant that a lot of revision was required – all while managing the new pandemic reality and full-time jobs.

Finally seeing the completed work, I am so excited about what this textbook can do for raising the bar for natural refrigeration installations around the world – not only from a safety point of view but also in terms of efficiency. However, it is not just about improving these systems, it is also about driving the move away from harmful, climate-heating and water-polluting refrigerants.

I firmly believe that by making this knowledge more accessible, we can greatly accelerate the adoption of natural, clean cooling technologies around the world – something that is more urgent than ever.

Happy learning!

A word of thanks

Allow me a few lines to thank the incredible team who made this journey to an English natural refrigerant textbook possible. Without everyone's hard work and patience, "*Natural Refrigerants: Applications and Practical Guidelines*" would not exist.

First and foremost, I would like to thank Bernd Hansemann, who always kept things moving and never lost hope that we would one day arrive at a complete product.

Thank you to Prof. Kauffeld, for his vision, his long hours, and trusting us to translate the book.

Thank you to all the authors, for taking the time to rework and improve the translated manuscript; also to the legend himself, Andy Pearson, for getting involved with the revisions; and everyone else who worked behind the scenes.

Of course, thank you also to all the companies that supported the financing of this book project by placing an advertisement of their specific natural refrigerant solution. Without your support we would not be able to offer this book at such a reasonable cost. It is exciting to see such a variety of companies offering components, systems, and knowhow for, and with, natural refrigerants in all applications. It's an ever growing community we are very happy about!

Last but definitely not least, I want to thank the persons I relied on the most – Jan Wisniewski, Maureen Garry, and Joseph Herzog – our English native-speaking proofreaders who ensured the best quality of the text.

I remain convinced that all this hard work will be worth it in the end.

Ilana Koegelenberg
ATMOsphere Co-Founder & Market Intelligence Manager