

Arno A. Evers

The Hydrogen Society



... more than just a Vision?

With a Preface by Prof. T. Nejat Veziroğlu



H₂YDROGEIT
Verlag

Arno A. Evers **The Hydrogen Society**

... more than just a Vision?

Arno A. Evers

The Hydrogen Society



... more than just a Vision?

With a Preface by Prof. T. Nejat Veziroğlu

H₂YDROGEIT
Verlag

No part of this publication may be reproduced or distributed in any form or by any means, or stored in a database or retrieval system, without the prior written permission of the publisher. This applies in particular to duplications, translations, microfilm production and storing and processing in electronic systems.

Any information in this book has been established to the best knowledge of the author and has been checked with reasonable care by the publisher. No responsibility can be accepted for any information which may be incorrect.

German Library Cataloging in Publication Data:

A catalogue record for this book is available from the German Library at:
<http://dnb.ddb.de>

Discover more at:

www.hydrogeit-verlag.de
www.hydrogenambassadors.com

ISBN 978-3-937863-31-3

Publisher: © Copyright 2010 Hydrogeit Verlag
16727 Oberkraemer, Germany

Printed and bound in Germany by:
adame Advertising and Media GmbH, Berlin
First published in Germany, April 2010

Printed on Cyclus Print made of 100 percent recycled fibres,
certified by The Blue Angel eco-label

Art Director, Illustrator, Type setting and DTP:
Thomas Schirmaier, Kommunikationsdesign
Munich, Germany
[E-Mail: design@t-schirmaier.de]

Research, consulting and final editing:
Daniela Peschka, Arno A. Evers FAIR-PR, Starnberg, Germany

Lectorate: Erik Wilhelm, CTO, VirVe, Zurich, Switzerland

Arno A. Evers asserts the moral right to be identified
as the author of this work.



Prof. T. Nejat Veziroğlu, President, International Association for Hydrogen Energy (right) and Dr. Yaacob Ibrahim, Minister for Environment and Water Resources, Government of Singapore (middle) met the author Arno A. Evers at the World Hydrogen Technologies Convention (WHTC) 2010 in Singapore.

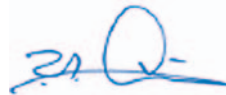
Preface

Fossil fuels (i.e., petroleum, natural gas and coal), which meet most of the world's energy demand today, are being depleted fast. Also, their utilization is causing global problems, such as the global warming, climate change, ozone layer depletion, acid rains, oxygen depletion and pollution, which are posing great danger for our environment and eventually for the life in the planet Earth. Many engineers and scientists agree that the solution to these global problems would be to replace the existing fossil fuel system by the Hydrogen Energy System. Hydrogen is the most efficient and the cleanest fuel. Its combustion will produce no greenhouse gases, no ozone layer depleting chemicals, little or no acid rain ingredients, no oxygen depletion and no pollution.

The book "The Hydrogen Society – more than just a Vision?" covers the concept and the developments relating to Hydrogen Energy from the beginning of 20th century on, follows historical and logical sequences showing that a real renewable Hydrogen Society is

achievable, and it would be the permanent solution to the global energy and environmental problems caused by the fossil fuels. It elucidates the developments in energy area in general, and Hydrogen Energy and Fuel Cells areas in particular. Following the adage "One picture is better than one thousand words", the book is lavishly illustrated. The conclusion is that the Hydrogen Society is not just a vision, and should be realized in a not too distant future, ensuring that the Planet Earth will be hospitable to life and the humankind will have clean and abundant energy.

I strongly recommend this excellent book to energy engineers, industrialists, environmentalists and decision makers, as well as to those interested in the future of humankind and the welfare of the planet Earth.

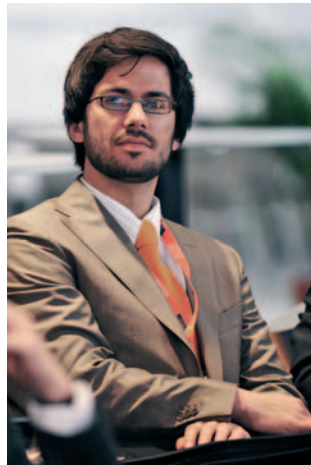


T. Nejat Veziroğlu

President, International Association for Hydrogen Energy (IAHE)

Foreword

Comments by an insider
by Erik Wilhelm (Canada),
former Hydrogen Ambassador at
the HANNOVER FAIR 2006,
current PhD candidate
at ETH Zürich, and Co-Founder
of VirVe Transportation 2.0



If you have not yet met Arno A. Evers, then it's about time that you did. Without exhausting my entire reserve of superlatives prematurely, I shall simply say that he is one of the most convincing visionaries for the transition to a hydrogen energy system that I have ever had the pleasure to meet. His sincere concern about the challenges facing our society and his strong belief in the solutions he presents in this book make it a pleasure to read. It is rare for an author to capture so much passion about a subject so concisely.

I came to know Arno, unsurprisingly, because of our mutual interest in fuel cell technology. Arno and his team selected two colleagues from the University of Waterloo and me to be 'Hydrogen Ambassadors'. We were flown, together with our recently-developed fuel cell-powered diver propulsion system, to the Group Exhibit Hydrogen and Fuel Cells at the HANNOVER FAIR 2006. And one day later, I found myself under bright stage lights explaining to the most important players in the fuel cell industry what the 'Hydrogen Ambassadors' pro-

gram was all about. I must have passed this trial by fire, because I have worked under the same lights in Hannover for the past two years, and was asked to write a few words to introduce Arno and his book.

In the book's title, Arno asks if the often discussed 'Hydrogen Society' is simply rhetoric or if there is hope of seeing it realized, and in the text he reflects on the lack of widespread implementation of fuel cell and renewable hydrogen production technologies. His book methodically outlines the weaknesses of our current energy system and then describes a set of technology solutions which could make the system both more robust as well as more sustainable. Foremost among these technologies are innovative methods of producing 'golden hydrogen' renewably from closed loop solar thermochemical cycles (which sounds complicated but is explained clearly in the book). Arno has succeeded in presenting his ideas so that they are understandable to all, and makes expert use of diagrams and images throughout the book.

Only through the hard work of 'Agent Provocateurs' such as Arno A. Evers can our society move towards a more sustainable future. His passion for the advancement of fuel cell technology animates every page of this book, and after you have finished reading it you will feel optimistic about the future of renewable hydrogen technology, as well as feeling that you have known Arno for years.

Contents

.....

PAGE

07	Preface by T. Nejat Veziroğlu
08	Foreword by Erik Wilhelm
12	Introduction
16	Why Promote Hydrogen: An Illustrative Interview between Concerned Citizens

20 **1 Nothing is Infinite: The Heavy Hand of Fossil Fuels**

22	1.1 Energy Supply and Consumption in the World
26	1.1.1 The Shaky Balance: Global Energy Consumption
30	1.2 Energy Supply and Consumption in Germany
34	1.2.1 Act Naturally: Renewable Energy in Germany

38 **2 Turning on the Light: The Process of Electricity Generation**

40	2.1 The Process of Electricity Generation
44	2.2 Initial Spark: Electricity from Fossil Fuels
46	2.3 Onward, Backward: Electricity from Nuclear Energy
50	2.4 Onward, Upward: Electricity from Renewable Energies
52	2.4.1 The Winds of Change
54	2.4.2 Seeing the Sun: Electricity from Solar Power
60	2.5 Population without Electricity

64 **3 The Grid: A Matter of Perspective**

74 **4 Consumer Electronics: A Spoonful of Ingenuity**

76	4.1 Evolution of the Apple iPod
80	4.2 From Me to You: Nokia Mobile Phones
84	4.3 Where has all the Power Gone: Daily Energy Losses





PAGE

88	5	Up, Up and Away: The Making of Hydrogen
90	5.1	Hydrogen and the Laws of Physics
92	5.2	The Long and Winding Road: Hydrogen Production from Fossil Fuels
94	5.3	Under Research: Hydrogen Production from Nuclear Energy
96	5.4	Applied Thinking: Hydrogen Production from Renewable Energies
98	5.4.1	Hydrogen Production from Renewable Energies with Electricity
102	5.4.2	Hydrogen Production from Renewable Energies without Electricity
106	5.5	Here Comes the Sun
112	6	Roads to Reality: How Many Miles to Go?
114	6.1	Ticket to Ride: Can Cars Carry that Weight?
120	6.2	Residential Fuel Cells: Chemical Process to Produce Hydrogen
124	6.3	Virtual Fuel Cell Power Plants
128	7	Go to Where the Market is: New Pathways to a Hydrogen Society
130	7.1	A Question of Design or can 35 Locomotives Really Fly?
134	7.2	Form and Function Combined: The Personal Power Provider (3P+)
138	7.3	Fitting it all together: On the Way – to a Real Hydrogen Society
146	8	And in the End: Final Considerations and Future Prospects
156		Bibliography and Credits
160		Acknowledgements
166		About the Author

Introduction



It is said that the rate at which a country can spend its money depends on public revenue and the current state of its economy – at least this was the case before the financial crisis of 2008. The same principle applies to private household’s financial possibilities and, to a greater degree, to hydrogen, should it eventually act as an energy carrier. Not only is energy required to produce it in the first place, but also a variety of domestic resources are needed from which hydrogen is to be extracted. At present, most people are thinking of using electrolysis to make hydrogen. But if you look closer, electricity itself is not a primary source of energy either, but an intrinsically inefficient energy carrier. Has anyone questioned that lately?

The goal of this book is to take the reader on a journey through some basic facts which are considered from unconventional perspectives. Just as heat flows

spontaneously from a hot to a cold body or just as energy can neither be created nor destroyed, hydrogen must play by its own set of universal laws. If the target is to use hydrogen as an energy carrier, there are huge benefits to be expected, depending on how the hydrogen is produced. The problems lying ahead of us however, are of technical nature. They can be faced and overcome by the implementation of new and sophisticated technologies. This is a question of genuine hard work and ingenuity. It is not a question of money. The crucial factor will be the availability of time to let hydrogen become what it initially was intended to be: A real energy carrier, eventually replacing electricity.

The book will also address a number of other common misconceptions, above all concerning the generation of electricity, its distribution, and use. Although one third of the world’s consumption of fossil fuels is



That is the way politics is done today: The heads of the world's wealthiest nations gathering at the UN Climate Change Conference 2009 in Copenhagen, Denmark. Regrettably, no consolidated resolution was reached.

used in producing it, electricity is only available to a percentage of the world's population. Roughly one quarter of our world's population has neither access to electricity nor to a decent fresh or waste-water system.

Current energy systems are based on coal, oil, natural gas, and nuclear fission, depending on the circumstances in a given country and its access to today's "cheapest" (not necessarily on the most viable) primary energy resources. The effects on our climate and the environment by emissions and the huge losses within the production/distribution cycle, however, are neither discussed nor questioned. The better we understand the evolution of industrial societies, the less surprised we will be about the connections between dependence on coal and oil, utilities, and the global economy.

But whether we like it or not, we live in a fragile world, of which we only have a single one to use. We can no longer afford our raging appetite for energy: Not only for our environment, but also for the next generation. Our present is their future!

Since the founding of the Group Exhibit Hydrogen + Fuel Cells at the HANNOVER FAIR in 1995, I have often been asked about the most significant changes within

this field of technology. Personally, I think the state of the art changed in two ways: much and little respectively. On the one hand, units have become smaller, more digitalized, more industrialized and even more efficient. On the other hand, only very few are thinking about working on the origin of the hydrogen as an energy carrier. There are many different ways to produce hydrogen which will be explained in this book. Not all of these procedures are benign or harmless to the environment.

In fact, the current production of hydrogen often obscures its true primary energy carrier. It is externally sold, with more or less powerful public relations or sometimes with ignorance, as "100 percent clean, 100 percent steam", although it was created in most cases from fossil fuels in a process called steam reforming. Politicians and media representatives readily jump on the bandwagon, because they just do not question the manufacturing process of hydrogen. Often they even do not care and do not want to know. This applies to administrators and other officials as well.

This book differs essentially from other books you might have read about hydrogen and/or renewable

energies. Take it not as a primer, but as a chance to excite imagination and to question existing structures. I have traveled to over 100 hydrogen and fuel cell conferences worldwide, where in most cases I took the chance to look behind the curtains of the energy industry. Throughout these journeys a collection of over 300 Energy Images and 50 Energy Ideas has been created.



Young Chinese learning. According to China's newly released data, a total of 7.5 million university graduates were seeking jobs in 2009. – Might one of them initiate a change in our inefficient energy system?

Some of them will be presented in this book, but to see the full list go to: www.hydrogenambassadors.com

Clean, renewable energy independence is not a far-fetched dream anymore. It is real, and just two steps are necessary to achieve it: a rethinking of the existing energy industry, followed by an active and sustainable transition to a slower-paced and more efficient and thus lower energy society. This should, in my opinion, be implemented in the near, foreseeable future, based on direct solar hydrogen as the main energy carrier.

We need to change the course of events now, not only through smarter technology or more renewable energy systems. What we need are significant changes to our energy system. It has to be done – the sooner, the better. To achieve this goal we need strong and inspired people with endurance who acknowledge the big picture and who are also able to turn desire into reality. It needs all of your passion and stamina as well as your knowledge and craftiness. Follow me as I guide you through the endless possibilities of our progress towards a better future energy system.

Why Promote Hydrogen:

An Illustrative Interview between Concerned Citizens

.....

To the unaided eye, the night sky is sprinkled with some two thousand stars, each appearing as a bright pinpoint of light. Yet their consumption of hydrogen is tremendous. Our sun – a mid-sized star – consumes 600 million tons of hydrogen per second, converting it into 596 million tons of helium. What about the remaining 4 million tons? It is converted into energy, according to Einstein’s famous formula $E = mc^2$ and finally reaches the Earth to sustain us all.

But hydrogen’s importance to us begins closer to home. Together with oxygen, it forms the oceans and lakes on the earth’s surface and the clouds in our atmosphere. Moreover, its abundance in organic matter may determine the future of our energy supply and thus may help to ease pressing environmental and societal problems. Yet the challenges in handling hydrogen are significant. So rather than writing down the key

facts about hydrogen in plain text, perhaps a little illustrative interview will inspire you to approach the advantages of this energy carrier a little bit differently. At the same time, you might learn about some of its disadvantages.

Q: What’s the idea of using hydrogen as an energy source?

A: It is an energy carrier, not a source of energy.

Q: Oh, I am sorry. I forgot.

A: We are all forgetful sometimes. Anyway, burned or used in fuel cells, hydrogen could serve as an energy carrier for all sorts of appliances, be it stationary or portable. When burned, it releases no greenhouse gases and when used in a fuel cell (together with oxygen) it generates electricity with only heat and water as useful by-products! Both rather important commodities!