Arno A. Evers

The Hydrogen Society

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... more than just a Vision?

With a Preface by Prof. T. Nejat Veziroğlu

H_2YDROGEIT Verlag

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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.

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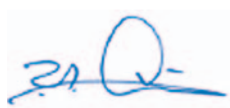
Prof. T. Nejat Veziroğlu, President, International Association for Hydrogen Energy (right) and Dr. Yaacob Ibrahim, Minister for Environment and Water Resources, Government of Singapore (middle) met the author Arno A. Evers at the World Hydrogen Technologies Convention (WHTC) 2005 in Singapore.

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.

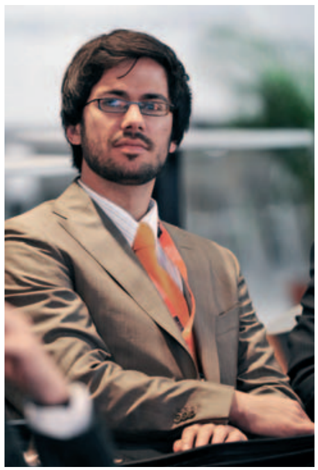
I strongly recommend this excellent book to energy engineers, industrialists, environmentalists and decision makers, as well as to those interested in the future of humankind and the welfare of the planet Earth.



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' program 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.

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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!

Q: Quite an amazing solution to solve our energy problem and loosen our dependence on fossil fuels. Or am I wrong?
A: Not quite. Currently, hydrogen has to be manufactured from hydrocarbon sources such as coal, oil or natural gas or be extracted from water through a process called electrolysis. But these processes are not the smartest ones.
Q: What's wrong with the electrolysis? It is just about water and electricity, isn't it?
A: Yes and No. Here you must ask yourself how the electricity was made in the first place. If made by fossil fuels, the hydrogen extracted from water is as unsustainable as the fossil fuels themselves. If made by renewable energy sources, the situation is a bit different.
Q: Sounds not quite convincing!
A: To support the production of hydrogen from "green" electricity, still a grid of substantial length and power is needed. Moreover, the electricity from wind power and photovoltaic is fluctuating by nature. But the membranes inside the electrolyzer do not really like to be operated with fluctuating current. They need pretty stable direct current (DC) power only. The grid consists of thousands of kilometers (in Germany 1.67 million km) of high voltage transmission lines, carrying only alternating current (AC). That means electricity from renewables must be converted to high voltage, transformed down again, and then rectified in AC/DC converters before fed into the electrolyzer.
Q: Rather complicated and not quite efficient at all. Might we be able to do something about it?
A: Well, it is a little easier with electricity made from hydro power, which is far more stable and can be converted in electrolyzers of different sizes into hydrogen. This has been done in Norway and Egypt successfully for many years. The hydrogen is mostly used there for the production of fertilizers.
Q: Are there any processes which do not need electricity in the first place?
A: Biomass is one solution. But we should keep in mind that land and plants might also be used for better, more important tasks such as food production.
Q: So what is there to do, then?
A: My favorite method is one in which hydrogen can be made in a two step water-splitting process with the help of nothing more than (concentrating) solar power.

Anyway, we need persistence and have to keep going until we find the most efficient mix of all renewable energy sources to produce hydrogen.

Q: Every element has special characteristics that need to be taken into account. What sets hydrogen apart from other fuel commodities?

A: Once you have real clean hydrogen, you can use it as a motor fuel, or as fuel for other useful applications. Hydrogen contains three times the energy of gasoline by weight, which means that only one-third as much fuel would have to be carried around to cover a similar driving range. However, it has only one tenth the volumetric density when used in liquid form and lesser still when it is stored as a compressed gas, necessitating large in-vehicle storage tanks. But to be honest, why shall we always carry enough fuel for a 400 km trip when our daily driving range is not more than just a tenth of that? And a hydrogen powered fuel cell vehicle would have a greater operational efficiency anyway.

Q: Exactly. And transit buses or trucks would have the size necessary to accommodate the storage of a sufficient amount of hydrogen. What about metal hydrides?

A: Some metal hydrides absorb hydrogen when exposed to the pressurized gas somewhat like a sponge soaks up water. Once they are heated or compressed, the hydrogen is released. But the weight of the metals makes this storage system quite heavy. Yet another approach could be come from nanoscale engineering. Due to the large surface areas with relatively small mass, some nanosize structures are considered as potential materials for high capacity hydrogen storage. Theoretically, every atom within a nanotube could hold on to one hydrogen atom until needed. But these are still dreams of the future. Good that we have them.

Q: Speaking about future, what's your suggestion in finding the right approach to run a Hydrogen Society?

A: A business-as-usual approach is useless. Once you try to generate, store, and transport hydrogen from fossil fuels or other inefficient processes you have already lost. We need to think smaller. By creating single, integrated units which may fit in everybody's garage or basement, we could produce only the amount of hydrogen which is really needed. To do so, we have to tap all renewable energies in sensible ways. We have to work with nature, not against it. During the day, the hydrogen we produce can be used for our electricity supply, heating, and hot water; during the night we can use it to fill up our car. In this way, the car could also be seen as the ultimate hydrogen storage system.

Q: I hope that we will get there sooner than later.

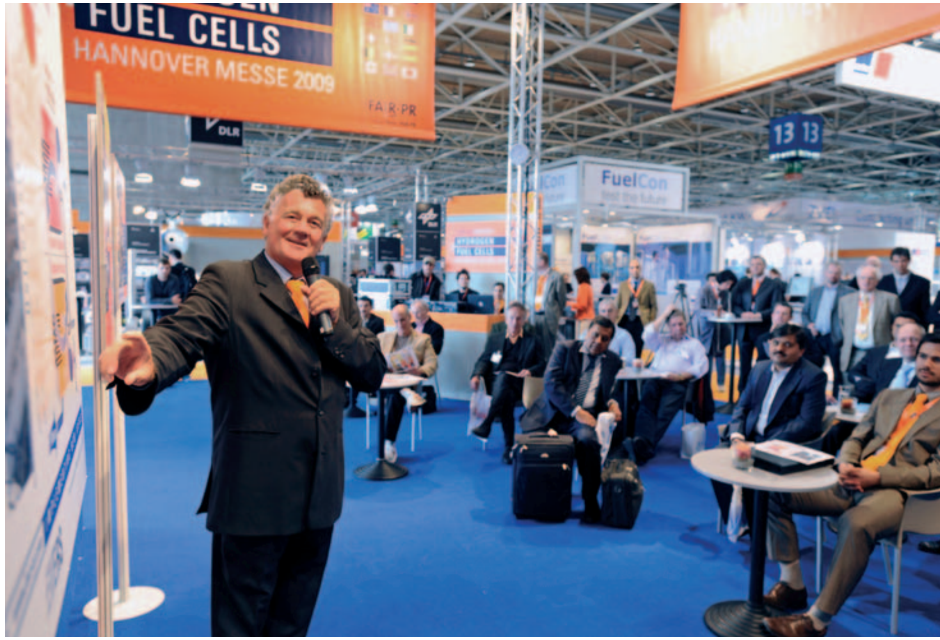
A: I am quite confident as this solution is too smart to be ignored. Whether our location is a city, a town, or a remote community, hydrogen would enable us to power our future as a green, maybe even golden energy carrier for all of life's necessities. Just imagine, power will not only be bought by the people, it will be also be produced by them. That's all that is needed and that's all that this book is about.

Q: How can we get there?

A: Unfortunately, only with hard thinking and lots of hard work. But the rewards we all reap will be far beyond our imagination. This applies also to the billions of people who do not have access to any decent energy supply right now. They deserve it as much as we do.

Q: Makes me curious.

A: Me, too.



Arno A. Evers on stage at the 15th Group Exhibit Hydrogen + Fuel Cells at HANNOVER FAIR 2009

1

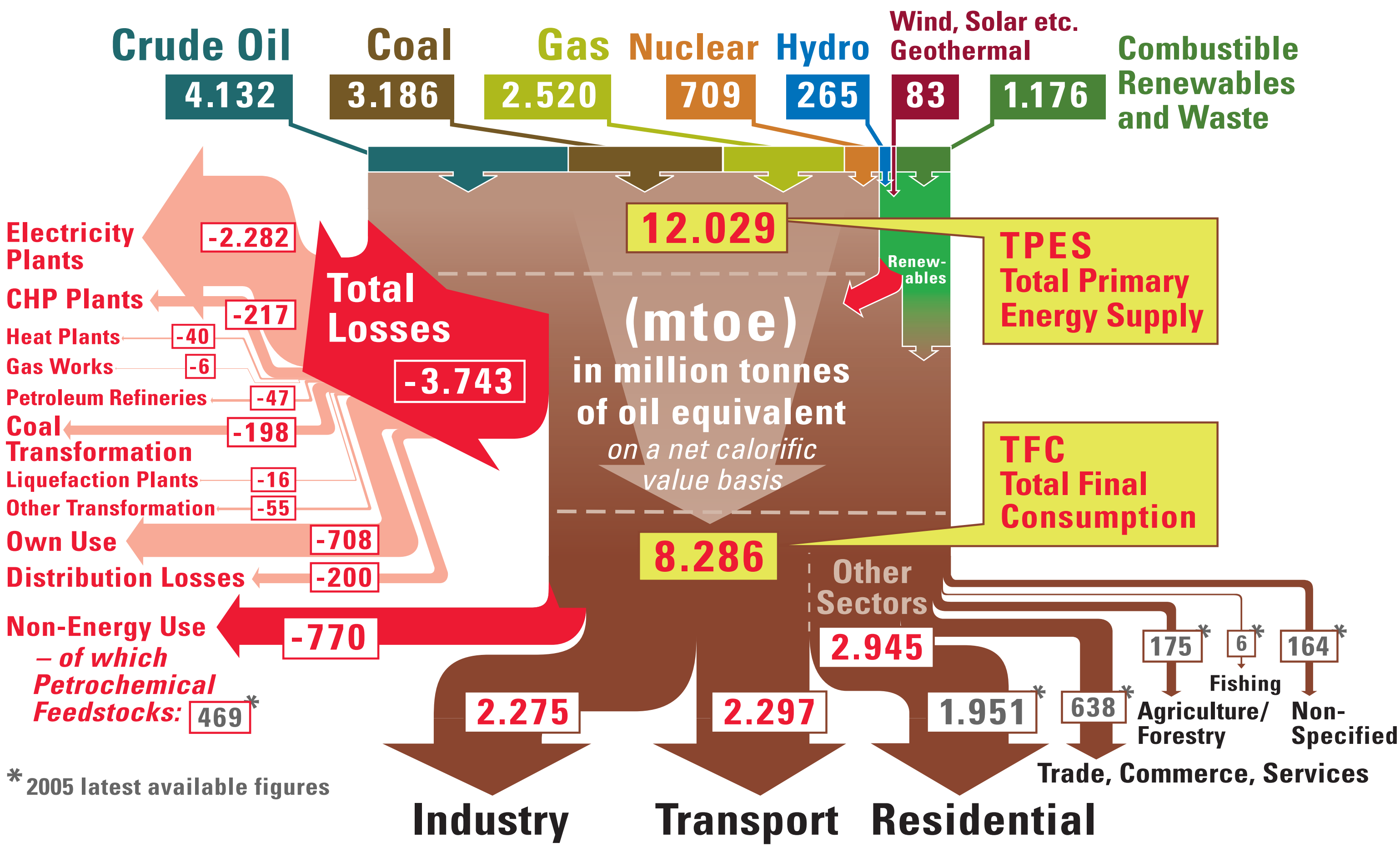
Nothing is Infinite: The Heavy Hand of Fossil Fuels

When we began to utilize fossil-fuel resources in the mid 1800s, we didn't just increase our standard of living by discovering clever ways to exploit our natural environment. We also began to deplete resources faster than nature can replenish them, and in the process alter whole ecosystems and drive up the natural levels of greenhouse gases (GHGs) in the atmosphere. While we can see and feel our impacts on the Earth's environment already, no one can predict definitely how much global warming will ultimately occur by burning fossil fuels, or what effects this warming may have. Recognizing these problems, let's begin our journey into the realm of energy with the elementary facts of its supply and consumption.

Energy Supply and Consumption in the World

In the most basic sense, the "energy balance" of the world can be viewed as out of "balance" (Figure 1.1). Why do I think so? Just stand back and see for yourself, that our energy economy runs primarily on non-renewable energy sources. And that is not a recent development, but has been going on since the beginning of industrialization. In fact, industrialization was powered by the utilization of fossil fuels. What we currently have is a huge deployment, or better, exploitation of primary feedstocks like coal, crude oil, natural gas and nuclear energy. There is little renewable energy used except for some combustibles and wastes, which are simply burned in furnaces. An exception, of course, is hydro power. Fossil fuels only develop under special environmental conditions taking million of years of burial, chemical reactions, and high temperatures. Today, we are harvesting those hidden treasures from inside the earth at an overwhelming rapid pace, changing our environment on a truly global scale. 88 percent (!) of our energy supply in 2007 was from fossil or nuclear origin.

Common sense tells us that the amount one takes of a given object (non-renewable resources) depends on its availability in a given system (Earth). If there is no or little chance of replenishment, then one must take a supply adequate for the duration of the journey (some billion years). At this point we do quite the opposite: at the current annual demand of fossil fuels, the proved reserves will be exhausted within the next three to five decades. But our generation takes the energy system for granted, although it is only one and a half centuries old. As long as the petrol at the fuelling station is cheap, and as long as the light goes on when we turn the switch, life is good. What's left for the next generation appears not to be of any interest.



Data Source: International Energy Agency. Key World Energy Statistics 2009. Paris, France 2009

Figure 1.1

World Energy Balance 2007

The end of the oil-age is predicted, and, as the resources diminish, the drilling is getting deeper and – in the truth sense of the word – dirtier. Drilling in pristine environments is under political debate, and we are even willing to invest huge amounts of money, energy and man power to extract oil from tar sand and oil shale, mostly located in remote parts of Canada. Both processes are extremely destructive to the environment and their profitability is more than questionable. For example, about 28 cubic meters of natural gas and four barrels of water are consumed while processing two tons of tar sands into one barrel of oil.[1] A costly and energy intensive process which is only viable when the price for oil is about US$ 65 a barrel.

The challenges to accomplish the supply of our energy needs are just as shocking as the aforementioned exploration front. You will notice from Figure 1.1 that there is quite a gap between our Total Primary Energy Supply (TPES) and the Total Final Consumption (TFC). What caused this difference? Actually, most of it is losses in the power plants themselves, foremost in the production of electricity. Electricity plants are not only by far the worst energy converters worldwide, but also by far the biggest producers of GHGs and other environmental unfriendly emissions. In fact, the order of magnitude is remarkable: The losses in more than 50,000 electricity plants worldwide amount officially to 2,282 million tonnes of oil equivalent (Mtoe).

This figure on its own is quite remarkable, but it gets scarier indeed if you compare it with the final consumption, let us say, of ALL industry activities worldwide. The losses occurring in the electricity plants are nearly equal to the energy consumed in the entire industry sector (2,275 Mtoe). That means, if you and I would have the power to shut down the entire industry sector worldwide for a given amount of time, we would save less energy than what is lost by the operation of those power plants. This is a very clear message to us

The Boxberg Power Plant is a lignite-fired power station consisting oft three units in Boxberg (Saxony), Germany. The 1,900-megawatt plant is the tenth dirtiest power plant in Europe. While consuming 50,000 tons of coal daily, it emits 1.1 kg of CO_2 per kWh produced.

1) http://www.energybulletin.net/node/1894

2) In 2008 Exxon Mobil posted a record profit of US $45.2 billion (bn) while British Petroleum "only" earned US$ 25.6 bn.

all, which, to be honest, first surprised me and then made me rather sad. Why is this not even discussed? Why does nobody think about this and why does nobody tackle this dreadfully inefficient system?

Simply put, it is all about economics. In fact, utilities and energy companies like ExxonMobil or British (Beyond) Petroleum are earning billions of Euros per year and their profit margins will only increase when demand exceeds supply.[2] Exploration, mining, and production processes will be paid for by the consumers anyway, the only real loser is Nature.

No doubt, new ideas for a more sustainable energy generation and supply chain are already here, but most of them are regarded as impractical, too expensive, or plain silly. Instead too many people spend too much time trying to keep the ailing system running. They try to improve the efficiency of fossil-fuelled power plants so that more energy is generated per unit of GHGs produced and/or more otherwise "waste" heat from the generation process is used via combined heat and power (CHP) technology. But the problem remains: the supply is finite. And this is a fact that we must be prepared to deal with.

In addition, the coolers seen on the left emit water vapor (steam) which is the most abundant greenhouse gas, if it gets up in higher levels of the atmosphere.

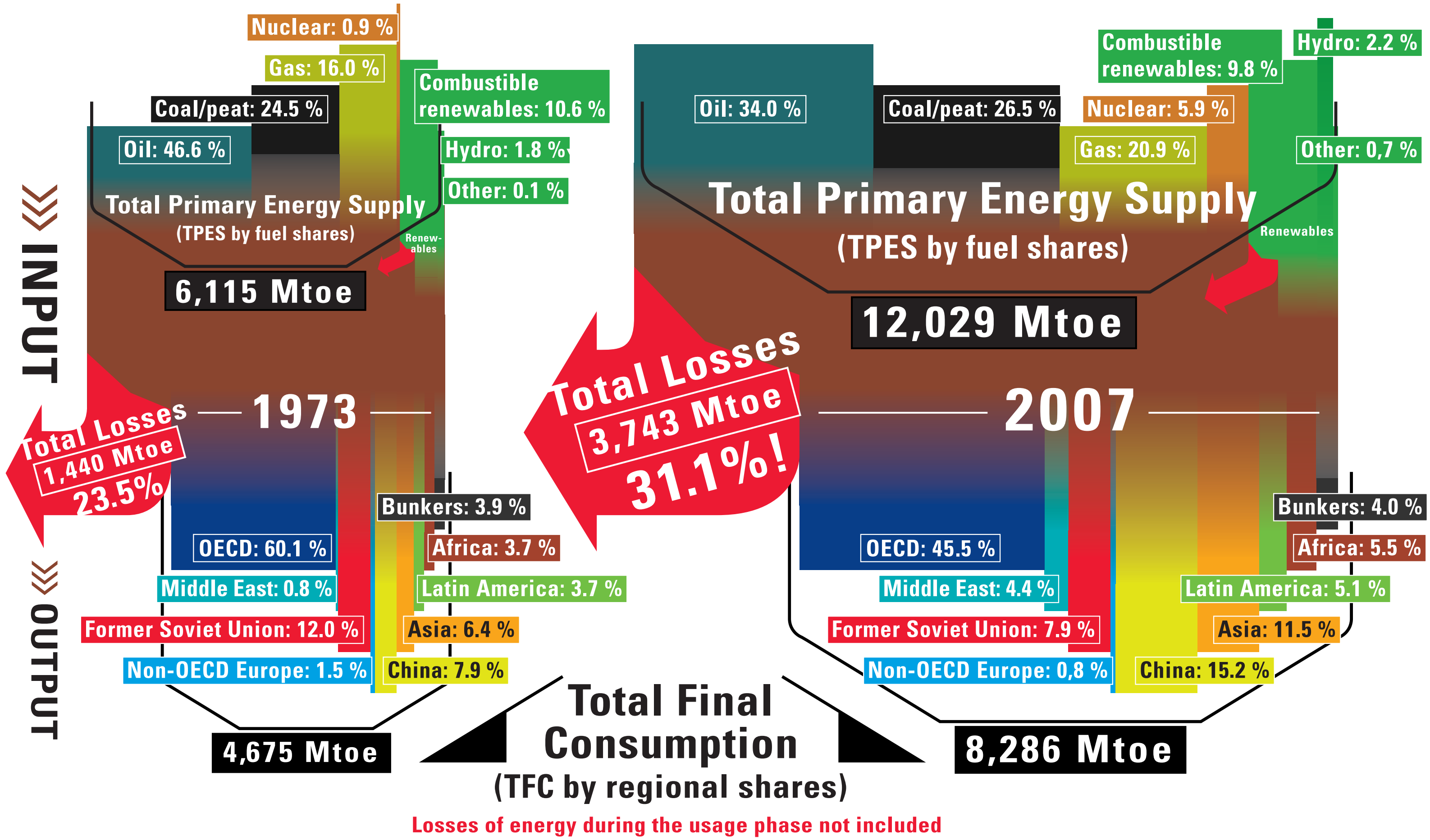
The Shaky Balance:
Global Energy Consumption

The Total Final Consumption (TFC) worldwide grew from 4,675 Mtoe in 1973 to 8,286 Mtoe in 2007 (Figure 1.2) with 88 percent derived from the combustion of fossil fuels and nuclear power. This is equivalent to an average power consumption rate of 96,349 terawatt-hours (TWh) in 2007.

At first the increase in the OECD countries from 2,809 Mtoe in 1973 to 3,770 Mtoe in 2007 seems to be modest for a 34 years time span. However, the OECD countries, with 18 percent of the world's population, consume 45.5 percent of the energy produced worldwide. Meaning that they use about four times more energy per person than the global average, and thus are also responsible for about half of the global emissions of carbon dioxide (CO_2) and other GHGs.

But when thinking about the world's energy consumption, one has also to think about China. This huge country with 1.3 billion (bn) inhabitants is advancing fast. The standard of living of most Chinese has improved markedly since the Chinese economic reform in 1978. Even the financial crisis, which started in 2008, has not affected them too much. Their gross national product (GNP) is still rising with two digit numbers. Unfortunately, China depends on huge coal deposits for its economic growth. In real figures, China's final energy consumption in 1973 was 369 Mtoe (8 percent of the energy produced worldwide) compared to 1,259 Mtoe (15 percent of the energy produced worldwide) in 2007. Emissions have risen by 5.7 percent per annum between 1973 and 2007 mainly because of the use of coal, which increased levels of CO_2 by 4.8 bn tonnes over the 34-year period.

And the consumption is still increasing at a rapid pace. This can easily be imagined by anybody who has



Data sources: International Energy Agency. Key World Energy Statistics 2009. Paris, France 2009

Figure 1.2

World Energy Balance Comparison 1973 to 2007

ever been in China. On twelve journeys to the country from 2002 through 2004, I could see this development for myself. When returning after weeks or months, remarkable changes have taken place, starting on the route from the airport to downtown Beijing or Shanghai or to other mega cities. Similar contributions in the coming years can be expected from India.

Noteworthy is also the comparison of the energy supply to the energy consumption between 1973 and 2007. Here, the inherent losses of our energy system are hidden, which rose in the given time span from 1,440 Mtoe (23.5 percent) to 3,743 Mtoe (31.1 percent).

Impressions from Shanghai, China in 2004.
Many of the old houses in the foreground have vanished to be replaced with skyscrapers; many of the bicycle or scooter drivers have been upgraded to become car drivers, in the process gaining immense economic and personal mobility benefits. On the downside, however, the transport sector could account for 60 percent of China's oil consumption by 2020. Not to mention the consequences for human health and the environment.

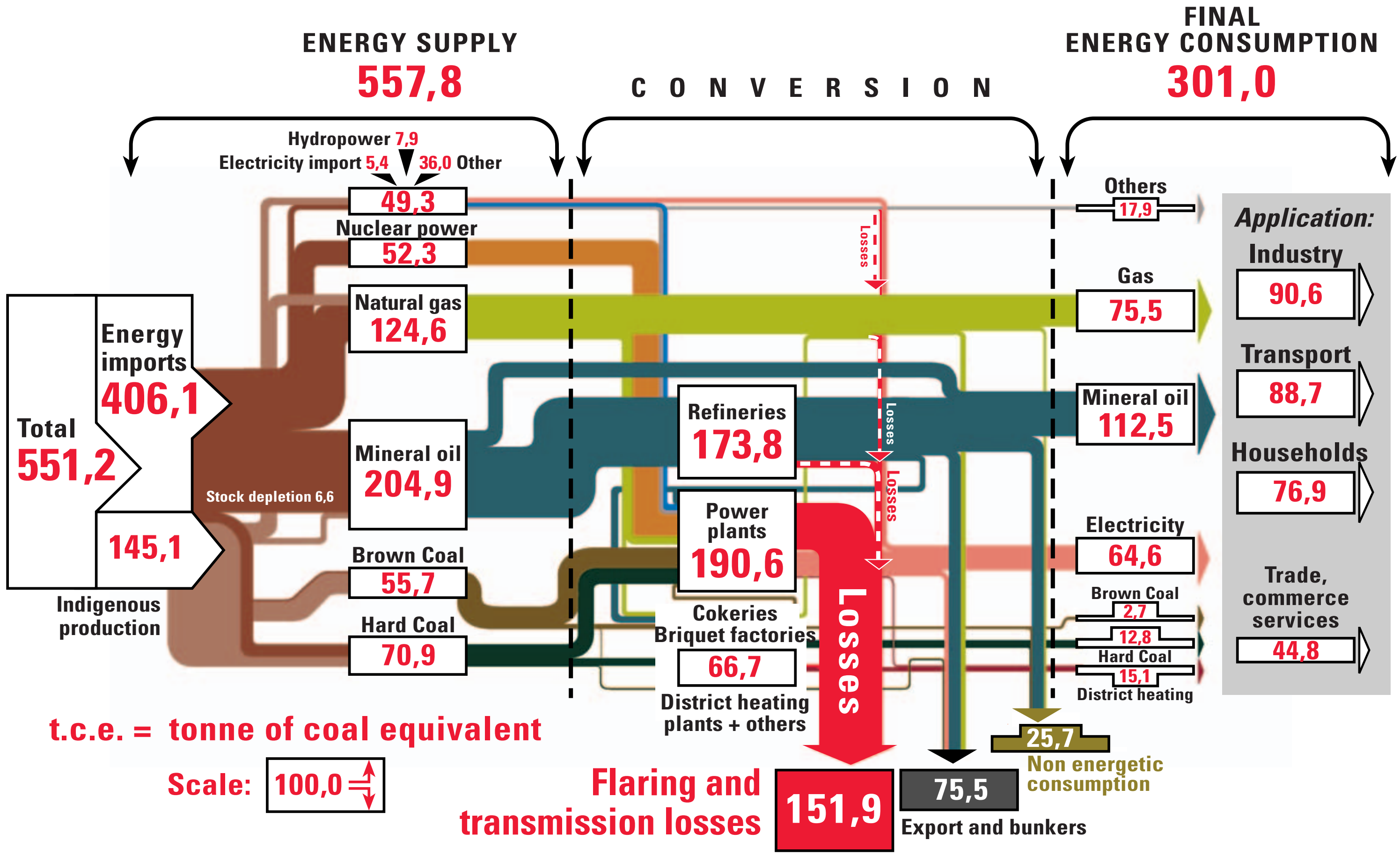
Energy Supply and Consumption in Germany

For decades, Germany's autonomy has been put at risk through its dependence on other countries for its primary energy supply. In 2007, 84 percent of Germany's primary energy was imported (Figure 1.3). Germany is, like many other countries, importing coal, crude oil, natural gas and uranium for nuclear energy. Coal is by far the most used primary energy for the production of electricity in power plants.

Despite the fact that domestic renewable sources are heavily supported by the government, the utilization of renewable energy (RE) such as hydro, wind, biomass, solar and geothermal power, is still relatively low at 6 percent of total energy supply in 2007.

Another disadvantage is that nearly all electricity made by RE is fed into the grid. This is not necessarily clever, as the conversion and transport losses for RE are thereby drastically increased. If the renewable energies would be fed in near the point of usage, the system would be much more efficient. Biomass is more versatile, as it is either used in burning wood in households (most of the time for heating), or utilized in power plants of different sizes which burn biomass and waste for electricity production.

Looking at one year provides interesting insight. 151.9 million (m) tonnes of coal equivalent (t.c.e.) of flaring and transmission losses can be identified. This might sound insignificant, but this represents twice the annual energy use of all German households. These losses are even 75 percent higher than all the energy used by the transportation sector. What might cause such immense losses? Only very few know the answer: These losses are suffered in thermal power plants during electricity generation, according to the laws of physics. The majority of these losses occur in coal



Data Source: Arbeitsgemeinschaft Energiebilanzen e.V. Energieflussbild (Detail) 2007. Berlin, Germany 10/2009

Figure 1.3

Energy Balance Germany 2007 in million t.c.e.

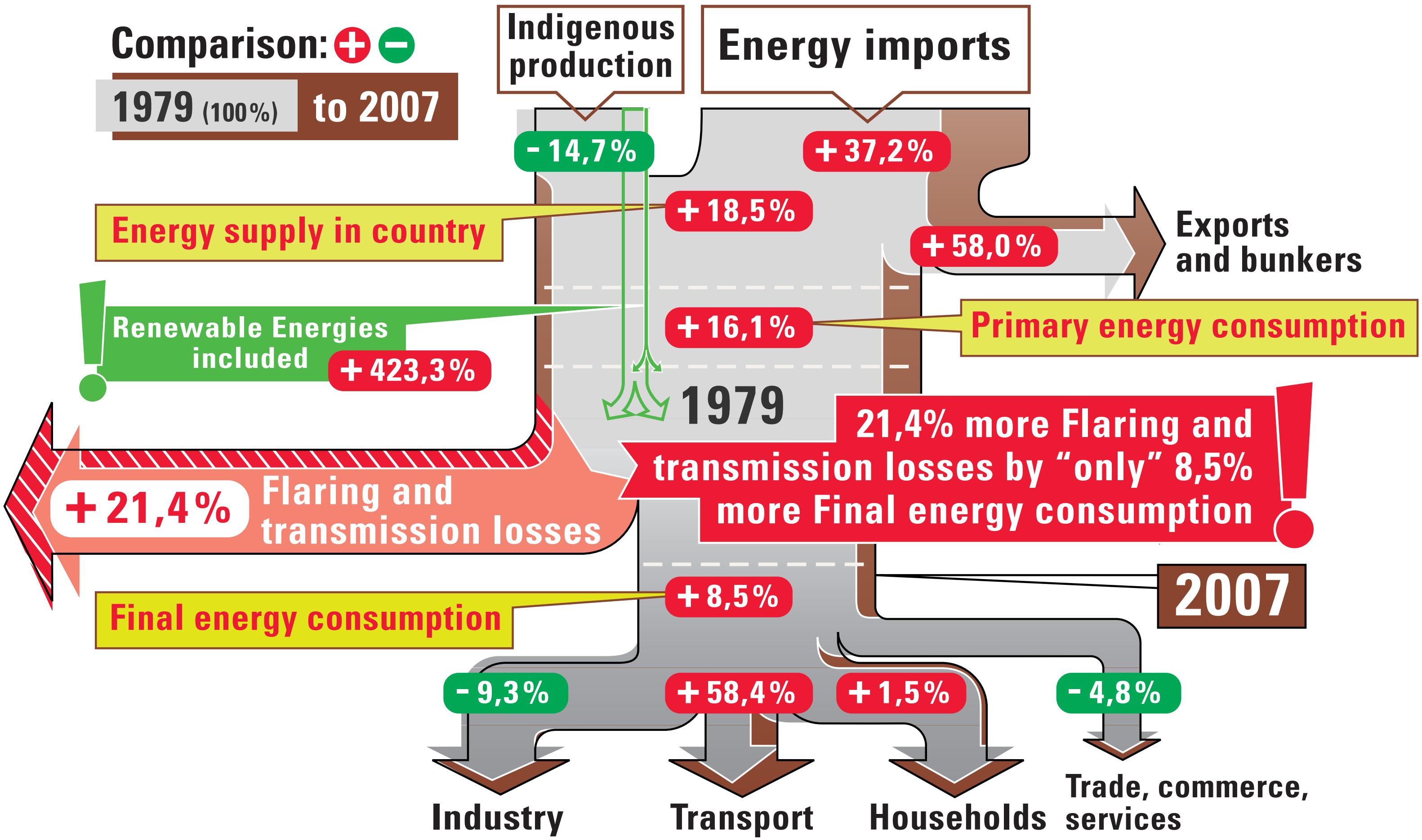
power plants. This is further explained in chapter 2.2 Initial Spark: Electricity from Fossil Fuels.

Now that the context is established, what to do with the knowledge? To better understand the development in Germany over the last 28 years, I have compared the figures from 2007 with the ones from 1979 (Figure 1.4). These 1979 figures have been published by my former employer, Dipl.-Ing. Dr.-Ing. E.h. Ludwig Bölkow in his book: "Decisions for a long-term energy policy" (published 1982).[4]

So what has changed through the seemingly ever-evolving, energy-efficient energy technology installed in Germany from 1979 until 2007? The rather disappointing result is: not much. In fact, the situation is even getting worse. Despite all political assurances that energy efficiency was increasing, the opposite actually occurred. Energy imports increased by 37 percent, while domestic production decreased by almost 15 percent. In Germany the share of renewable energy rose by a significant 423 percent, but only because its proportion in 1979 (with 6 m t.c.e.) was negligible. At that time, RE meant wood in households (for heat) and hydro power forelectricity generation in power plants. Flaring and transmission losses have increased by 21 percent over the past 28 years. For comparison: the final energy consumption grew by only 9 percent.

Anyone who today speaks about efficiency and / or energy savings, as many in Germany do, should first consider starting with savings possible at the conversion step. Since the late 1990's, the German government has continuously stepped up its funding for renewable energy generation. Nevertheless, it still falls short when compared to the overall amount of energy produced by fossil fuels. The next chapter gives a short overview.

4) Bölkow, Ludwig. Entscheidungen für eine langfristige Energiepolitik. Page 15



Data Sources: Bölkow, Ludwig. Entscheidungen für eine langfristige Energiepolitik. Page 15; Arbeitsgemeinschaft Energiebilanzen e.V. Energieflussbild der BRD 2007. Berlin, Germany 09/2009

Figure 1.4

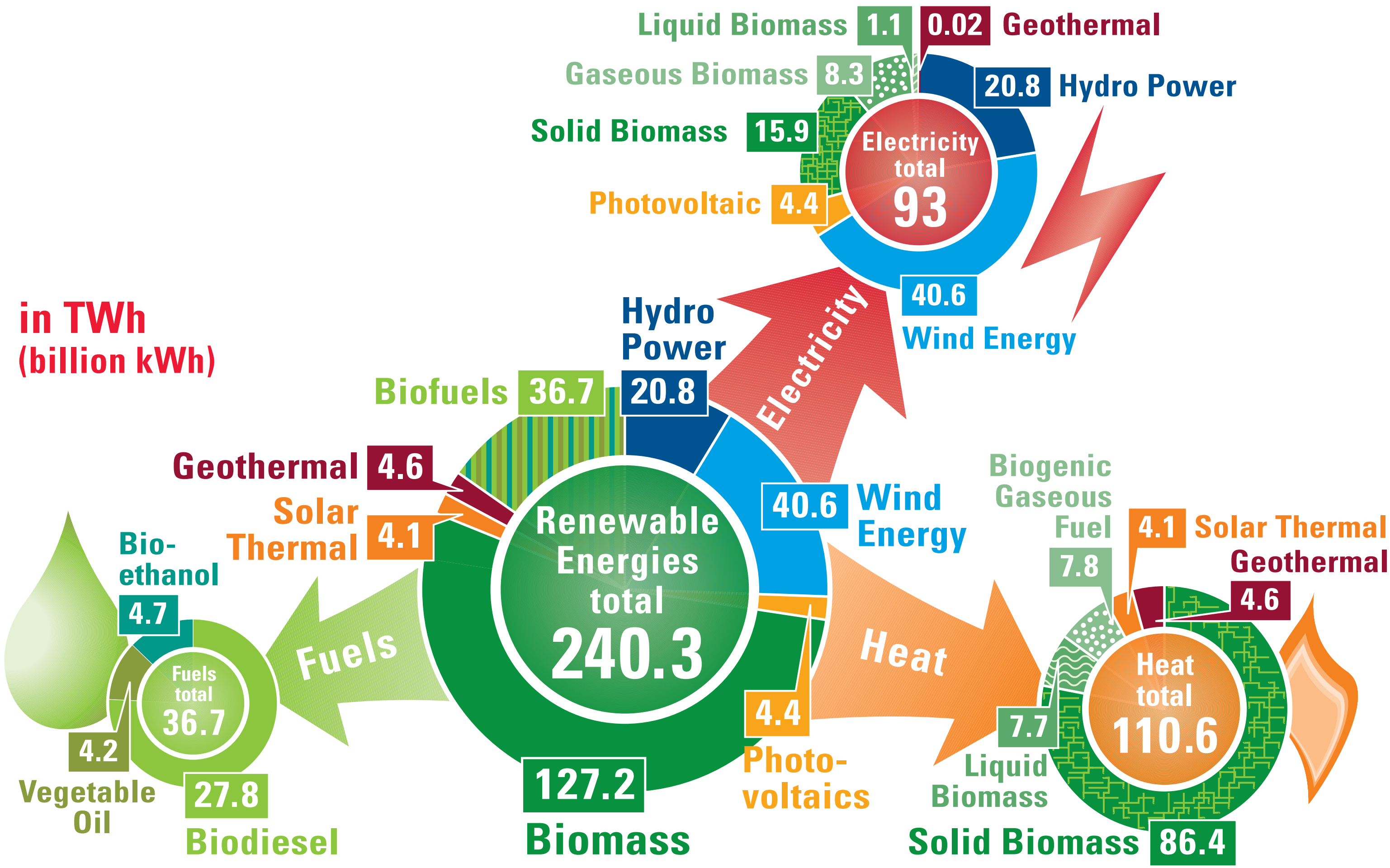
Energy Balance Germany Comparison 1979 to 2007

Act Naturally:
Renewable Energy in Germany

When thinking of renewable energy (RE) in Germany, most people imagine wind, photovoltaic and maybe a little bit of hydro power. The reality, however, is different (Figure 1.5). By far the biggest source of RE in Germany is biomass (including bio fuels) and, at 163.9 TWh, represents 68 percent of the total final energy consumption of renewable energies in 2008. Modern Germany uses no more RE than it did in the past: where agricultural and forestry products such as forest timber, fast growing tree species, and cultivated energy or cereal crops as well as cutting waste from landscape conservation were employed to improve the standard of living. The current number two renewable is wind energy, followed by hydro power and waste.

What is true is the fact that RE use has steadily increased over the last several years, especially after the German Renewable Energy Act in 2008 (Erneuerbare-Energien-Gesetz [EEG]) came into force. RE have a share of 9.5 percent of the total primary energy consumption, 15.1 percent of the total electricity consumption, 7.7 percent of heat and 5.9 percent of fuel consumption. Of secondary importance, however, are the shares of solar and geothermal energy as RE sources.

All of these naked figures are not saying too much on their own. They must be brought into perspective. The politicians do this easily in saying that the renewable energy sector created a total workforce of 278,000 employees in 2008, compared to 249,300 in 2007. However, the majority of those, namely 95,000 employees, worked in the biomass sector. All in all the German Federal Environment Ministry (BMU) has calculated that a total of Euro 30.7 bn was being spent for investment and operation of RE in 2008. This is split up into



Data Source: BMU-Brochure. Erneuerbare Energien in Zahlen – Internet-Update. Berlin, Germany 12/2009

Figure 1.5

Renewable Energy Sources as a Share of Energy Supply in Germany 2008

37.8 percent (Euro 11.6 bn) for photovoltaic, 35.3 percent (Euro 10.8 bn) for biomass, and 18.9 percent (Euro 5.8 bn) for wind energy, with the remainder for hydro and geothermal power.

As nice as this all sounds, some observations must be made. First: The EEG introduced on April 1, 2000 in Germany evolved into an international model for a reliable development of the renewable energy industry. Some elements of the EEG are: an unobstructed grid access at regulated minimum prices, as well as investment tax credits and loan guarantees. It is said that this kind of regulation proved to be the most effective and most economical solution in the world, and is applied in a similar way in many countries. But effective for whom? For the grid operators? Or is it for the installer of large RE power plants which suddenly popped up in regions where electricity production is unlikely to be efficient? For years, the supply of components for photovoltaic panels or wind mills could not keep up with demand. This kept prices artificially high and held back innovations.

The other element is the feed-in tariff (FIT) itself: FITs oblige the utilities to buy all the electricity generated from renewable sources at a fixed, above-wholesale price for 20 years. These costs are passed according to a complicated calculation to consumers in form of a higher electricity bills. The utilities were even smart enough to implement a paragraph in the EEG which allows them to collect a (not too) small amount of money for their "lost profit", due to the electricity supplied through RE. Meanwhile similar feed-in laws have been implemented in most European countries.

The other disadvantage, at least as I see it, lies in the nature of the actual feed-in procedure.

Suppliers of electricity from PV, who are participating in the EEG, and nearly all of them do, get a fairly high amount of funding for each kilowatt-hour (kWh) fed into the grid (roughly Euro 0.35 at the moment depending on the size of the installation). For the kWh they are using in their own house, they earn around Euro 0.23.[5] In both cases, they have to install inverters after their photovoltaic array, which is producing direct current (DC) power. They than either use their own electricity as alternating current (AC) power or feed it into the grid, in this case at 230 Volts AC. The inverters are, by their nature, creating losses. Wind energy, biomass,

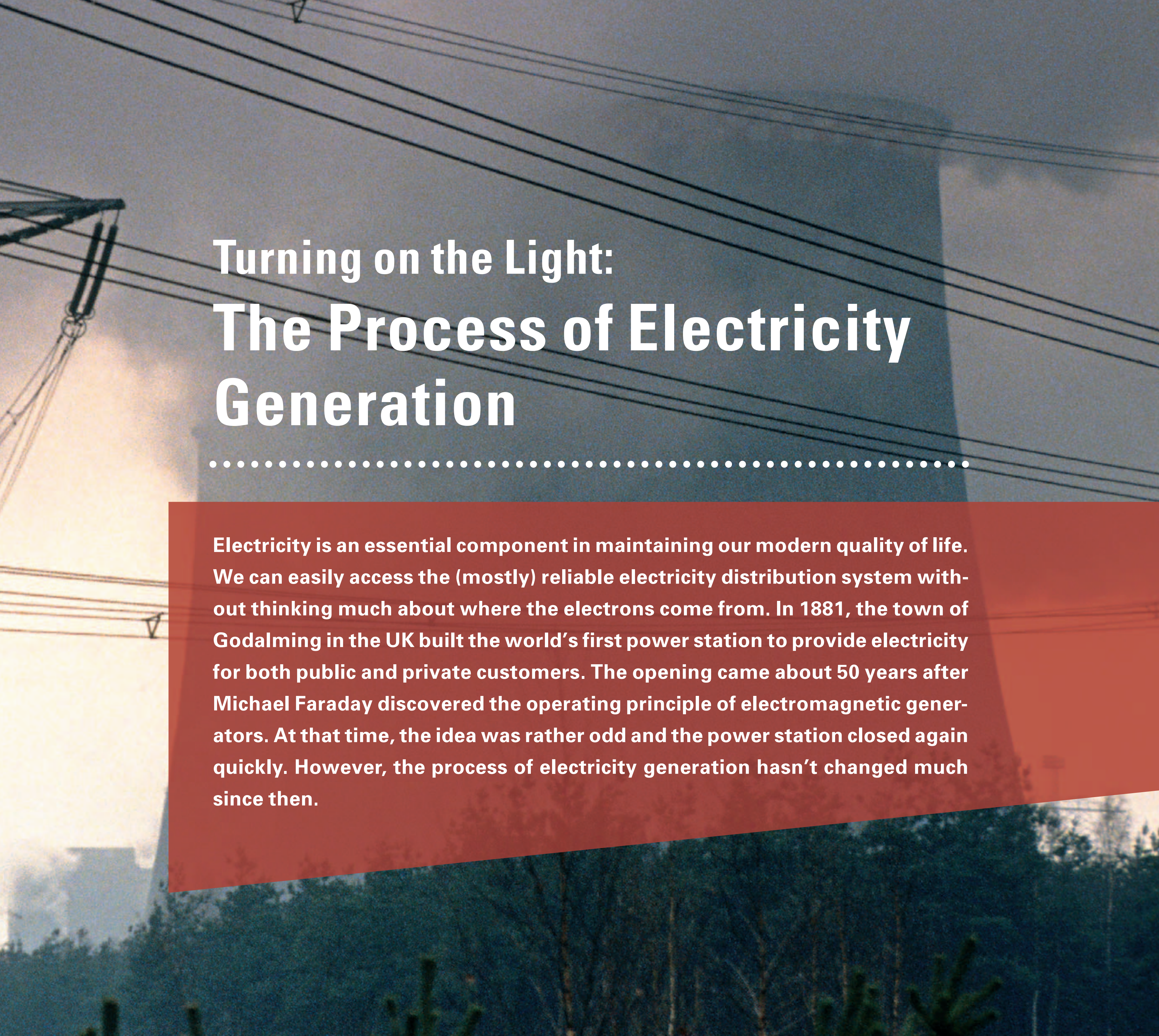
5) On average, the price for 1 kWh of electricity is around Euro 0,20 in Germany.

and large hydropower plants are normally totally fed into the grid, in this case even transformed up to 15 kV or more, depending on the location. Again losses are created. In doing so, the electricity created by the renewable is supporting the electricity network and thus the owners of these grids. But the FIT begins to sway anyway. The German government plans to cut the support for new photovoltaic rooftop installations by 16 percent from June 2010. Similar announcements have been made by France.

My proposition would be to use the electricity from RE directly where it is produced. That means there is no need to feed it into the grid, but to use it locally in houses, villages, or communities. Here, of course, the question of energy storage arises, that might be solved by using electricity not as an energy carrier, but by using a completely new one, namely hydrogen. There are many ways to put hydrogen to work and we are getting there soon, but not until we have understood how electricity is produced in the first place.

Hand chopped firewood for heat/hot water and cooking in woodstoves is still used extensively in Germany. The bucket full of hard coal is also waiting to be burned.

2



Turning on the Light:
The Process of Electricity Generation

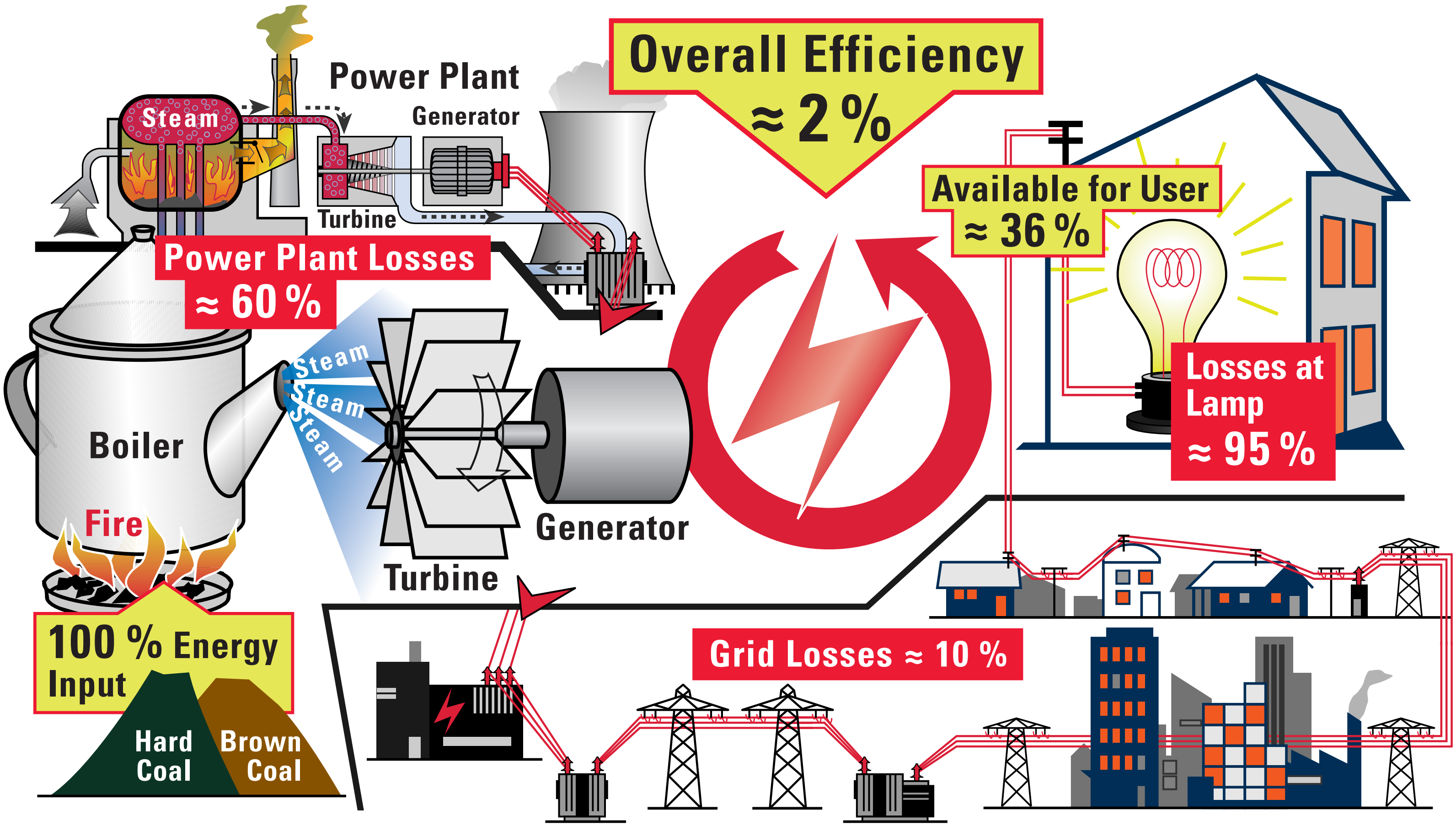
Electricity is an essential component in maintaining our modern quality of life. We can easily access the (mostly) reliable electricity distribution system without thinking much about where the electrons come from. In 1881, the town of Godalming in the UK built the world's first power station to provide electricity for both public and private customers. The opening came about 50 years after Michael Faraday discovered the operating principle of electromagnetic generators. At that time, the idea was rather odd and the power station closed again quickly. However, the process of electricity generation hasn't changed much since then.

The Process of Electricity Generation

In a furnace, water is heated by burning fossil fuels to produce steam which drives a turbine (Figure 2.1). The rotating axle of the turbine is attached to an electric generator that converts mechanical energy into electricity. During this process, about 60 percent of the energy input is "lost" irreversibly. The losses occur within the burning process (flaring losses), in the conversion of liquid water to steam, in heat radiation, as mechanical losses within the turbine and the generator, in cooling the steam after it has been used in the turbine, and in many other places.

The electricity generated at the power plants is alternating current (AC) at relatively low voltage because of isolation inside the generators. The electricity is then stepped up to high voltage using transformers, before being transmitted to substations located hundreds of kilometers away. Finally, the electricity enters, again via transformers, the low voltage distribution system for its use in homes, offices and factories. As an unavoidable consequence, at least another 10 percent of the electricity vanishes in transmission losses. Depending on the state of the grid in a given country, these losses can be even higher (see also chapter 3 The Grid: A Matter of Perspective).

Moreover, many of today's electric appliances are extremely inefficient, wasting much of the power they consume as heat. Approximately 95 percent of the energy consumed by an incandescent bulb is emitted as heat, only the remaining 5 percent are given off as light. In this case, when the entire cycle of generating, transporting and using electricity is considered, the electricity is delivered to the user of the incandescent bulb with an overall efficiency of just 2 percent. All these losses are simply accepted because the user, be it industry or



Data Source: Electric Power Industry, PennWell (1998); own investigation

Figure 2.1

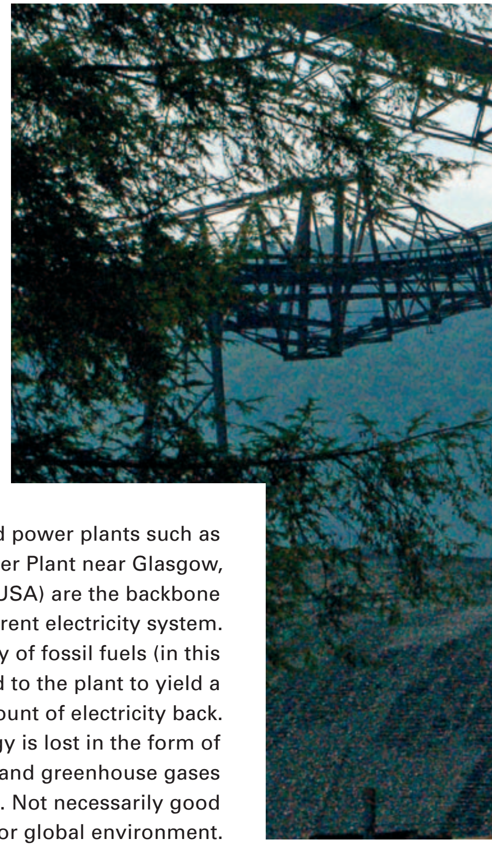
The Process of Electricity Generation

households, are paying all the losses with their utility bills.

As an example, here is the calculation for a utility which is running power plants and grid simultaneously: **fuel cost** (coal or whatever ...) **plus labour** (there are few staff needed to run a power station, rather little ...) **plus depreciation** (not much, as most power stations are rather old ...) **plus cost of the grid** (mostly unknown ...) Revenue: as found on the utility bill by the customer. The difference between cost and revenue turns out to be their profit. You can look for yourself at their annual balance sheets, to see how profitable this business is. Would this not be the case, the system would quickly find a way to change.

If the consumers were to be shown that they are not only paying the kWh logged by their meter, but in fact the coal which is shoveled into the power plants, they might start thinking about their energy-consuming behavior.

It is all a bit embarrassing, frankly. With all the progress made by modern technologies, we still use a rather old fashioned and not very smart way to produce, transport and to use electricity. Do we not have more imaginative ways of generating electricity? And if so, what options do we have to put us on another track? Which challenges do we face to make a change?



Fossil fuelled power plants such as the Kanawha River Plant near Glasgow, West Virginia (USA) are the backbone of our current electricity system. A large quantity of fossil fuels (in this case coal) must be fed to the plant to yield a small amount of electricity back. The rest of the energy is lost in the form of (unused) heat, and greenhouse gases and ash are emitted. Not necessarily good for the local or global environment.

Initial Spark:
Electricity from Fossil Fuels

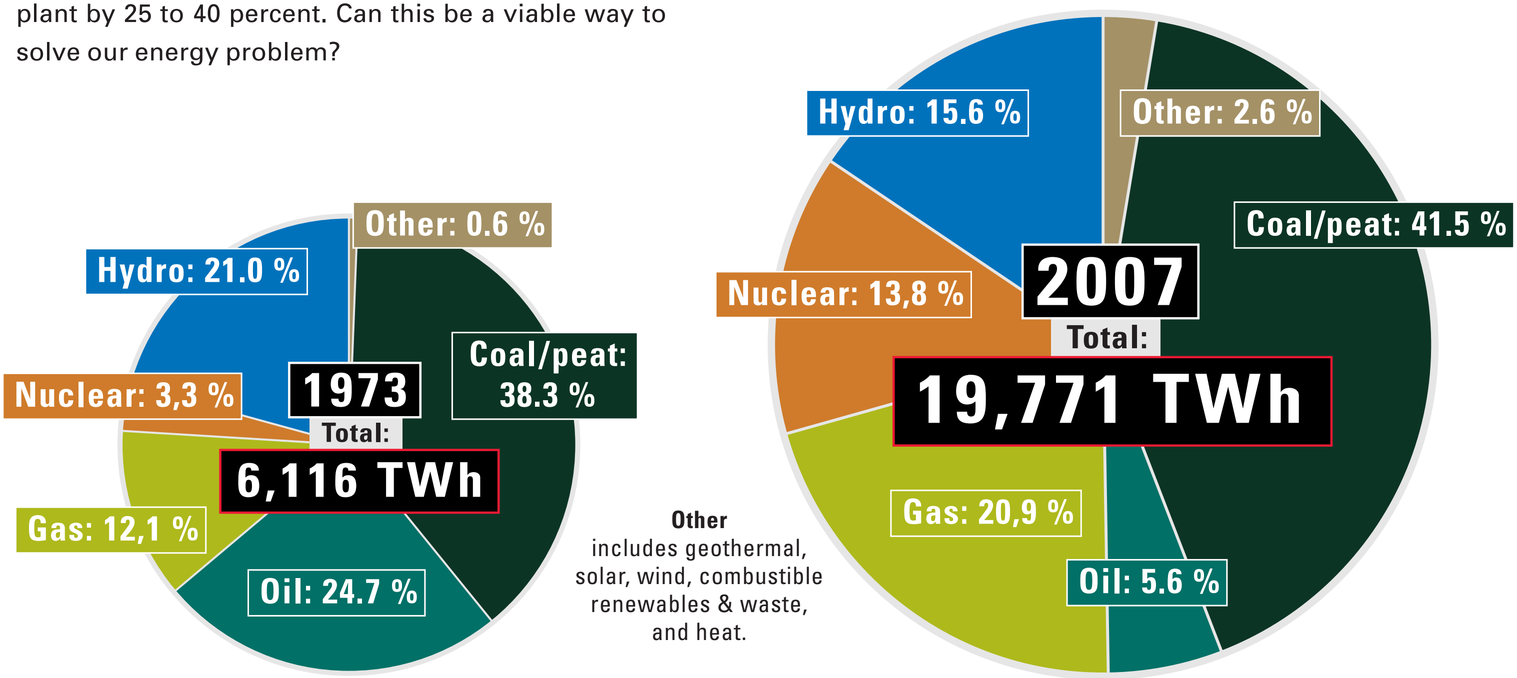
Between 1973 and 2007 the worldwide electricity generation increased threefold as the world became more and more dependent on electricity to meet its energy needs (Figure 2.2). Currently, and in the past, the supply is almost entirely based on conventional fossil fuels: they amount to worldwide over 80 percent of the generated 19.771 TWh in 2007. Coal has always been the major feedstock for electricity production, and this is projected to continue to be true into the foreseeable future. By world standards it is still the most accessible, cheapest, and most reliable source of energy. However, coal-fired power plants are also by far the largest source of carbon dioxide (CO_2) and other global-warming pollutants such as methane (CH_4) and nitrous oxide (N_2O).

The efficiency of fossil fired power plants range from 30 to 38 percent depending on the age of the plant and the technologies used. New technologies like the (ultra-) supercritical pulverised coal combustion or the process of integrated coal gasification combined cycle (IGCC) can raise the efficiency for electricity generation to 45 percent and to more than 50 percent respectively. However, the environmental damage remains the same, inducing further even unknown changes in the global climate system.

The only technology available to mitigate GHG emissions from large-scale fossil fuel usage is carbon dioxide capture and storage (CCS). CCS is a process whereby CO_2 shall be captured from gases that would otherwise be emitted via smoke stacks into the atmosphere, and then be injected into deep geologic formations for permanent storage. However, CCS already faces many challenges that are not only related to issues such as financing demonstration projects and in-

1) Minchener Andrew. Future Coal Supply Prospects. IEA Clean Coal Centre. London, UK 2009

tegration of adequate infrastructures, but also to efficiency. For example, capturing and compressing CO_2 would increase the fuel needs of a coal-fired power plant by 25 to 40 percent. Can this be a viable way to solve our energy problem?



Data Source: International Energy Agency. Key World Energy Statistics 2009. Paris, France 2009

Figure 2.2

Worldwide Electricity Generation*, Fuel Shares Comparison 1973 to 2007

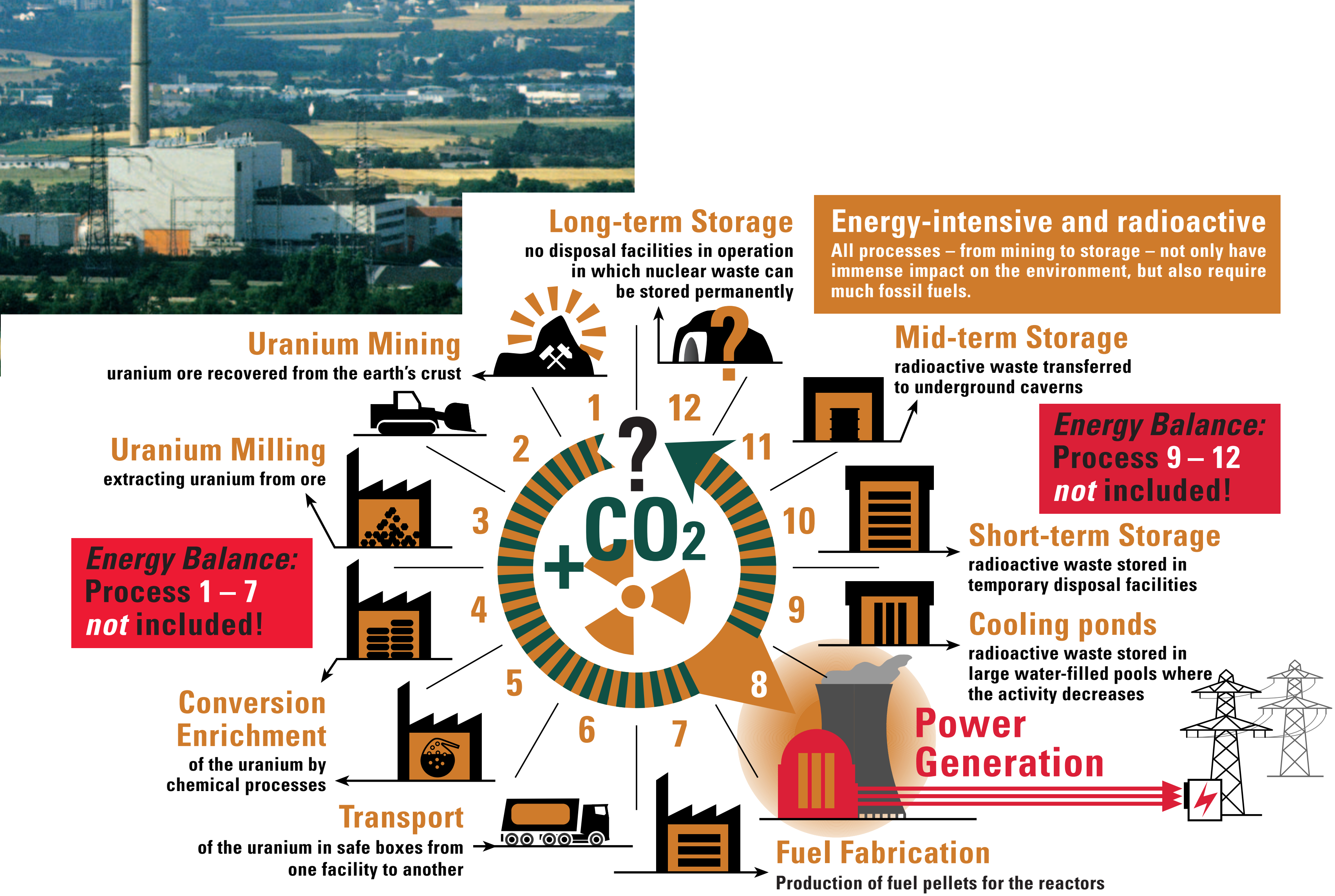
***Excludes pumped storage**

Onward, Backward: Electricity from Nuclear Energy

The fundamental principle for nuclear power generation was discovered by none other than Albert Einstein with his discovery that a little mass could theoretically be converted into enormous amounts of energy. This breakthrough is used in every nuclear power plant today. Nuclear power plants are fuelled by a naturally-occurring and thus finite element called uranium. Canada, Kazakhstan, and Australia are the top three producers, and together supply 59 percent of the world's uranium fabrication. Other important uranium producing countries are Namibia, Russia, Niger, Uzbekistan and the United States.

Some consider nuclear power plants to be a "clean" electricity source, since the plants themselves do not directly emit CO_2 and other GHGs. Nevertheless, the operation of nuclear power plants result in the immense environmental impacts which are displayed in Figure 2.3. After a cost intensive exploration process, uranium ore is recovered from the earth's crust under quite difficult conditions. It must be extracted from the mined ore using strong acids and bases, and then be converted into either uranium dioxide (UO_2) for heavy water reactors or gaseous uranium hexafluoride (UF_6) for light water reactors. Most reactors require uranium fuel to have a U-235 (an isotope of uranium) content of 3 to 5 percent. For this step, large amounts of electricity, mostly provided by fossil fuel plants, are needed to increase the actual concentration of 0.7 percent to 3 to 5 percent. Afterwards, the uranium is manufactured into fuel pellets by pressing powdered UO_2 or UF_6 into small cylindrical shapes and baking them at high temperatures, usually between 1,600 and 1,700°C.

Finally, energy is released in a reactor by controlled nuclear fission reactions just to boil water, produce



Data Source: Cameco Corp., Nuclear Fuel Cycle, http://www.cameco.com/uranium_101/uranium_science/nuclear_fuel/

Figure 2.3

Electricity from Nuclear Energy

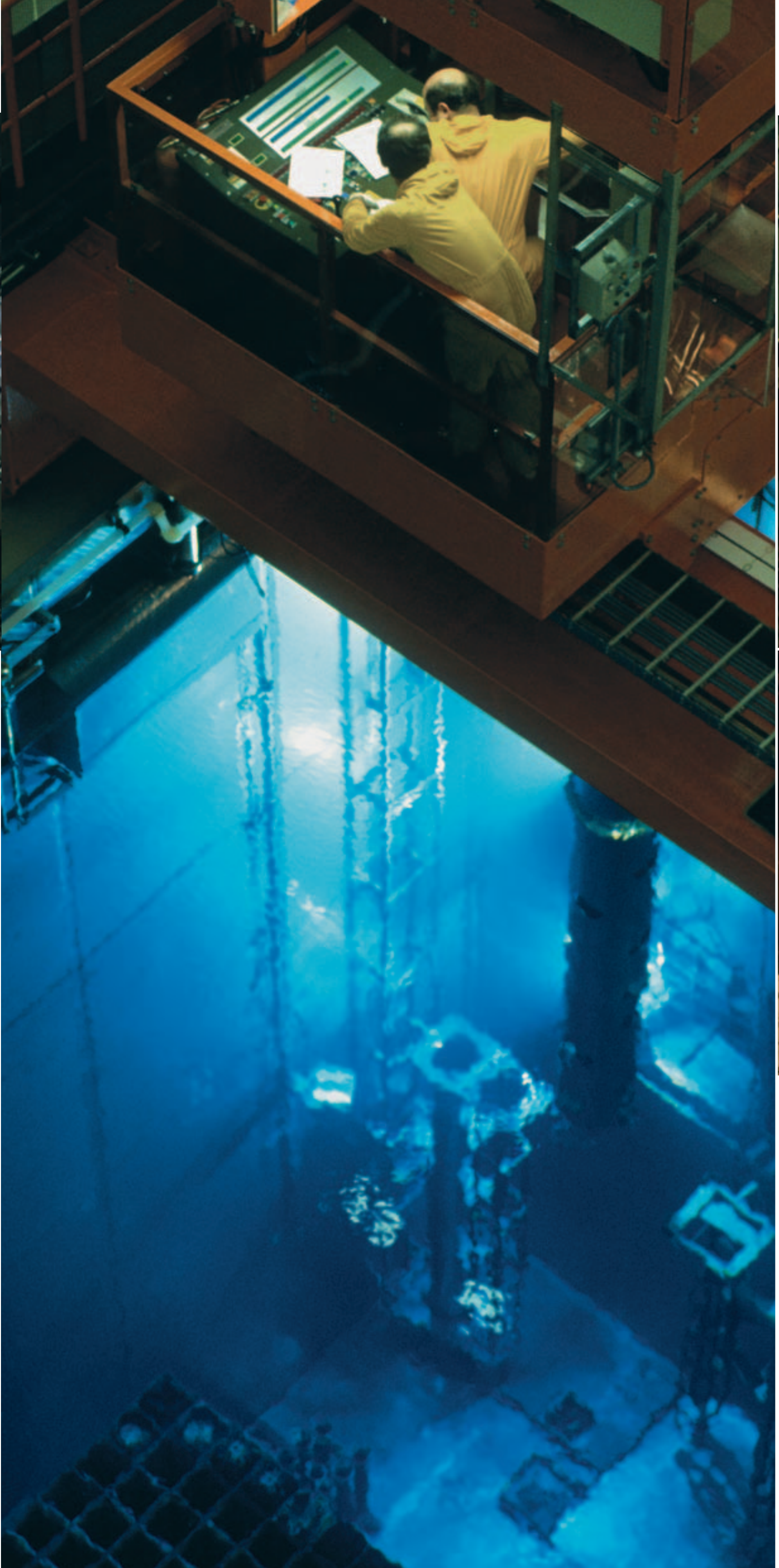
steam, and drive a turbine that generates electricity. This process alone has an efficiency of only 35 percent. For steam production and for cooling, approximately 2.5 times more water is needed for nuclear than is required for fossil fuel plants. This is the reason why nuclear power plants are located at rivers or lakes.

After the nuclear fuel is consumed in the reaction process, it is removed from the reactor and stored onsite in large water-filled pools for about five years. Later, the radioactive waste is transferred to underground caverns for medium-term storage. At present, there are no safe disposal facilities in operation anywhere in the world which can accept radioactive waste for permanent storage. A prevailing example is Asse II in Germany, a former subterranean salt mine research operation. Used as a radioactive waste disposal facility since the seventies, its storage has recently been found to be unstable. According to World Nuclear News, roughly 126,000 barrels filled with low-level radioactive waste including contaminated clothes, paper and equipment need to be brought to the surface for alternative storage.[2] A challenge involving approximately Euro 3.7 billion, and a rather gracious heritage for future generation(s).

Can a process like this that poses health risks exceeding that of any other process of electricity generation be called "clean"? I don't think so. We always need to keep in mind that already a minor failure in a nuclear power plant can create severe consequences for all forms of life on earth!

Impressions from the early stages of dismantling a 100 MW pressurized heavy-water reactor nuclear power plant in Niederaichbach, Germany. The target was to re-establish the site's original state of vegetation (so-called 'back to green field' approach). This nuclear power plant was only in operation for 18 months in 1973/1974.

2) http://www.world-nuclear-news.org/WR_Germanys_waste_removal_decision_1801101.html



Onward, Upward:
Electricity from Renewable Energies

Electricity from renewable energies, though accounting for a comparatively small portion of overall electricity supply (see Figure 2.2), have shown dramatic gains in recent years. There are five fundamental methods of transforming renewable energies into electricity:

Hydropower, the source for 16 percent of the world's electricity generation in 2007, is a process by which the energy of flowing water or tidal forces is harnessed to spin a turbine connected to a generator. There are new, huge hydroelectricity plants built in China and Brazil with capacities in the range of 14,000 MW to 22,500 MW. Worldwide, an installed capacity of 770 gigawatt – electric (GW_e) supplied more 3,190 TWh of hydroelectricity in 2007.[3]

Biomass is derived from plants, but also includes agriculture and food processing wastes or fuel crops that are specifically bred and grown for electricity generation. Direct combustion power plants burn the biomass directly in furnaces that supply steam to drive a turbine. Another process is the gasification of biomass. The derived gas can then fuel steam generators, combustion turbines, combined cycle technologies or fuel cells.

Geothermal energy is heat energy originating close to the earth's surface or in the earth's warm interior. The heat in the form of hot water or steam powers a turbine that generates electricity through a generator.

Wind power is produced by converting the kinetic energy of wind into electricity by using large spinning blades connected to a generator (see chapter 2.4.1 The Winds of Change).

Solar power is derived using energy from the sun. There are two main types of technologies for convert-

3) BP p.l.c. BP Statistical Review of World Energy June 2008. London, UK. page 38

ing solar energy into electricity (Photovoltaic and Concentrating Solar Power) which are explored in more detail in chapter 2.4.2 Seeing the Sun.

While it is true that renewable energy sources are environmentally-friendly, or "green", one has also to consider their feedstock. Solar, wind, hydro and geothermal energies are "free" at first glance, although they require huge land-use investments with environmental unfriendly footprints. The investment needed to build profitable power plants varies according to plant size. Biomass used for electrification has to be planted and produced somehow, if we do not want to depend exclusively on refuse or hazardous waste.

It is also obvious that electricity from renewable energies has considerable disadvantages in the way they are deployed today. First of all, and foremost, they are dependent on certain conditions (availability of wind, water, sunshine ...). At this time, most renewable sources are used to produce electricity which is fed into the grid. Hence hydroelectricity or wind plants are treated in the same way as "normal" conventional power plants. Due to their intermitted nature, this deployment method is overstraining the grid, which is additionally rather inefficient in itself. This fact is used by the grid operators as an argument to ask for governmental help to not only improve the grid, but to make it "smart". A topic which is already under political consideration, especially in the US. As part of The American Recovery and Reinvestment Act of 2009, more than US$ 3.4 billion shall be invested in smart grid technology development grants, and an additional US$ 615 million for smart grid storage, monitoring, and technology viability.[4]

But do we need an electricity grid at all? Hot water, for instance, can also be provided directly from decentralized solar thermal units by solar power or by biomass, with no electricity involved. A sensible and decentralized use of a combination of all renewable energy sources should not simply be a matter of lifestyle choice. This is a matter that has great environmental consequences. So let's have a closer look at two of the renewable energy sources.

4) http://www.recovery.gov/Pages/home.aspx?q=content/act

The Winds of Change

The use of wind power is not at all a new experimental technology. It was already used centuries ago for pumping water and for milling cereals. New, though, is its use to produce electricity which started after the first oil crisis in the seventies. At the end of 2008, the worldwide nameplate capacity of wind-powered generators added up to 121 GW, a mere of 1.5 percent of the world's electricity usage. But the rapid growth continues, with China doubling its wind power capacity for the fifth consecutive year since 2004, or with the USA becoming the leader in new capacity investment with US$ 24 billion invested.[5]

Today, nearly all large wind farms are connected to the electricity power transmission network (grid). Only in rare cases is the electricity used locally as well. This turns out to be a big problem for the grid-operating utilities, because electricity must be used as soon as it is produced. But how easily can you forecast when and where the wind will blow? You can't simply start a wind mill up when you need it most.

Thus, at least as the electricity grids are operated today, the intermittency of wind always requires back-

5) REN21. Renewables Global Status Report: 2009 Update. Paris, France 2009, page 8

The wind park in the San Gorgonio Pass Area near Palm Springs, CA was one of the first in the USA. The installed power of the individual windmills, of those several thousands are erected there, is between 65 and 1,000 kW. However, many of them are already around 30 years old; the investment should be more than amortized by now.

up systems with an equal amount of dispatchable generation capacity. Unfortunately, at the moment these back-up systems are mostly conventional power plants that do not have short run-up times. In addition to the unpredictability of wind, wind farms usually need high investments to be built, and are also very expensive to properly maintain.

Speaking from my worldwide observations, at least 20 percent of the wind mills are shut off for maintenance or repairs. What is even worse, they are often taken off the grid, because their electricity is not needed at that given moment. What a system, what a waste of resources. There are no commercially viable ways to store wind energy at this time, other than pumping up water electrically in water reservoirs. But this only makes sense when wind farm and water reservoir are close to each other.

To summarize: we have lost already as long as we hold on to our brittle centralized energy (grid) system – with or without renewable resources (see also chapter 3 The Grid: A Matter of Perspective). Why not use electricity produced by wind farms locally with clever storage in between?

The spatial proximity to high tension power lines, supplying the Greater Los Angeles area, is an advantage of the location. However, without transformer substations, even if they are made of wood as seen here, nothing really works.

Seeing the Sun:
Electricity from Solar Power

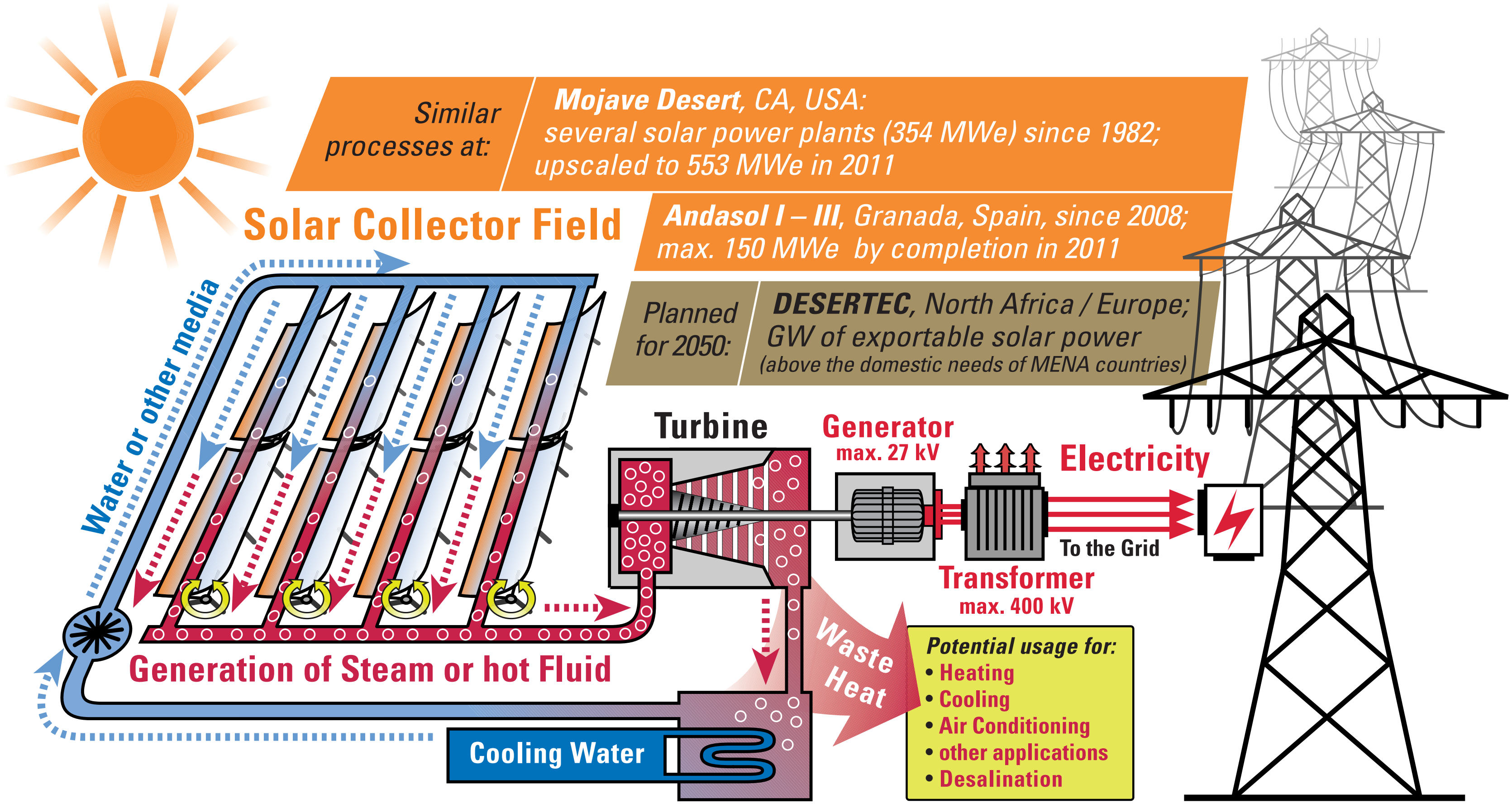
The amount of energy that comes from the sun is phenomenal: If we could somehow gather all the energy that reaches the earth on one day and store it, it would supply the energy needs of the whole world for almost 30 years.[6] Moreover, solar radiation is actually the sole source for fossil or renewable energy that we use today. Electricity from sunlight can be generated directly using photovoltaic solar cells, or indirectly as with concentrating solar power.

At present, PV is used primarily in regions where governments offer financial incentives for its installation, for example in Germany. Here the Renewable Energy Act (EEG) guarantees all owners of PV systems a fixed, above-wholesale price feed-in tariff for each kWh of electricity produced. This is, by the way, a pretty serviceable formula for the continuation of the firm, monopolistic structure of the present electricity economy. While it is true that this policy helps to pull PV into commercial deployment, this model also hinders a more rapid technological improvement of the solar cells. Even PV systems with poor efficiency will be sold anyway. The philosophy of the EEG was also imported by other countries, "… following the success of the German legislation …". Examining the fine print, those feed-in tariffs are not at all paid by the utilities, but by the electricity customers of a given country. In fact, the utilities are getting a refund for "lost profits" for each kWh fed into their grid.

Consider another interesting aspect: PV solar cells convert the sun's radiation into DC power on which most of our appliances actually run. But this power is converted into AC power by inverters and fed into the inefficient grid, only to be inverted again to DC. It somehow turns out that ideas which would eliminate central

6) http://www.altenergy.org/renewables/solar.html

Solar Millennium AG developed the first parabolic trough power plants in Europe.
The Andasol 1 plant in southern Spain has started operation in March 2009.



Data Source: www.shp-europe.com, own investigation

Figure 2.4

Scheme of a Solar Thermal Power Plant (STPP)

utilities are not quite welcomed. There is no question that we need to go solar, but we should do it a bit more wisely, shouldn't we? Especially considering the environmental impact of manufacturing solar cells and their low conversion efficiencies of roughly 15 percent.

At this point, the most cost-effective and efficient technology for converting solar power into electricity are huge solar-thermal power plants (Figure 2.4). Here, sunlight is gathered by a large solar-collecting field with parabolic mirrors, so called troughs. These collectors track the sun over the course of the day and concentrate the sunlight onto absorber pipes where the radiation is converted into heat. A heat transfer fluid which is circulating trough the pipes is heated up to temperatures of almost 400°C. The heat is used to generate steam with which electricity is then produced by conventional steam turbines. The process water is then cooled and returned to the cycle. The surplus heat could be used for heating, desalination, cooling, air conditioning, and other applications, but in most cases it is currently rejected to the atmosphere.

Solar-thermal power plants have been in commercial use for several decades now. The first plants have

7) http://www.solarmillennium.de

been operating in the Mojave Desert in California (354 MW_e) since 1982 and will be up scaled to 553 MW_e by 2011. Three new plants have come on stream in 2008 in Granada, Spain: Andasol I to III:[7] Each Andasol power plant covers an area of 195 hectares (about two square kilometers) with a collector area of 510,120 square meters (aperture surface). Approximately 90 kilometers of absorption pipes and curved mirrors with a total area of 580,500 square meters are also installed. All three solar power plants are at the moment the largest solar trough plants in the world, generating an annual net electricity output of around 150 gigawatt-hours (GWh) per plant. Thermal molten salt storage enables electricity production even during the night, or on cloudy days. The storage time, however, is calculated to be seven

Immense amounts of cooling water and an absorbing grid, capable of dissipating the electricity generated, are urgently needed to keep this process running. Unlike sun, water is hardly available in an arid regions. All in all a step in the right direction, but additional research has to be done to become much more effective with solar thermal power.

hours, which is in my opinion not quite enough, even for a cozy Andalusian night. I have visited both solar power plants, those in the Mojave Desert as well as Andasol in Andalusia. I was impressed by the sheer size of the installations. However, in both cases there was not even a sign, let alone an information center, explaining the technology and giving some answers to frequently asked questions. Considering the huge amount of money (and good ideas) invested in both cases, providing some information for the concerned citizens would be something to consider.

However, when you look at the websites of the operators, you can sometimes find explanations that make you wonder about this so called "green" technology, especially when you read that the amount of water needed to run the plant is: "... equal to normal agricultural use ..." at that given location. In Andasol, each plant requires about 870,000 cubic meters of water per year, which is mainly used for cooling the steam circuit, i.e. from the vaporization of water in the cooling towers.[8] So the plant operators not only have to capture the power of the sun, but also need immense amounts of water for cooling of the heat transfer media. As most solar power plants today are located in deserts, this physical necessity may be an obstacle to development on the long run.

Another restriction comes from the Spanish energy law itself, which states that each power plant is permitted to feed in a maximum of 50 MW into the grid. What an achievement.

This leads us to the planned DESERTEC project, which will, according to current plans, operate using more or less the same scheme. Here, the basic idea is to build huge solar thermal power plants and wind farms in the Sahara desert, and at the North African coast, to supply 15 percent of Europe's future electricity needs. Again, you need some kind of grid to transfer the power safely and without significant losses to Europe. The current proposals call for the use of High Voltage Direct Current (HVDC). In this context we learn that the transportation of electricity by high voltage AC, as it is done now, is ineffective. Good to know.

Various other technologies have been studied, developed and constructed in the field of solar energy, such as Solar Power Tower plants, which use an array of flat, moveable mirrors (heliostats) to focus the sun's

8) Ibidem, page 14

rays on a collector tower. The heat transfer media to produce steam for the turbine within the tower could be water, molten salts or compressed air. This technology is also suitable for a number of chemical high-temperature processes, such as direct solar hydrogen which will be explored in more detail in chapter 5.5 Here Comes the Sun.

Population without Electricity

Although most of us use electricity as if there were no tomorrow, we must be aware of the fact that at this point our current energy system relies almost exclusively on finite resources. Sooner or later new ideas and technologies must be brought to the forefront to supply our growing global population with the energy they need.

Have you ever imagined spending a full week of your life without electricity? Not just a brief power outage for a few hours. Many of the things we take for granted today would just stop running: No electric heat or refrigeration, no (traffic) lights, televisions, telephone or electric toothbrushes. Everything digital would be worthless. And life as such would start to become quite inconvenient, at least for us. Well, if you live in Africa or developing Asia, you may spent your entire life without electricity. Based on the World Energy Outlook 2009, the International Energy Agency (IEA) estimates that in 2008 the number of people without access to electricity was 1.5 billion or 22 percent of the world's population. Some 85 percent of those people live in rural areas (Figure 2.5). In most cases, those people do not even have access to a decent water supply and draining system.

The biggest energy poverty reduction so far took place in China and East Asia, where booming economies saw the number of people without electricity access fall to 195 million in 2008, from 241 million in 2001. Although the proportion of the world's population with access to electricity will rise over the next 20 years, the IEA still predicts more than a billion people without power in 2030. As a consequence, a lot of rural electrification programs and national electrification agencies have been created in these countries to monitor more accurately the needs and the status of rural develop-

Commuters leaving Manhattan, New York City, USA to the east via Brooklyn Bridge. The reason for this unexpected march: On August 14, 2003, a huge power cut grounded all air conditions units, elevators, subways, building-lightning, traffic lights and computers.

ment and electrification. But the question is: Who is better off? Those who have a close connection to their environment, who "live with the sun"? Or is it those who live in air-conditioned apartments and have never seen a cow in their lives? Is it necessary to have household appliances running all day, or is it more important to listen to a bird singing? Probably it is a mixture of both.

Hence our mutual target must be to reduce the number of people without access to electricity by 2030 at an even greater rate. How are we going to do that? Well, there are two ways: We could use more fossil fuels, and force them into a dependence on international energy companies at the expense of their culture and environment. Or we could try to implement a really smart system combining the decentralized use of all available renewable energies as primary sources. Maybe even with hydrogen as the main energy carrier. This system has to deploy fuel cells only at the point of usage, at the very end of the functional chain. We will get to more about this idea in the chapters 5 and 7, but first let's conclude our journey into the world of electricity with an analysis of its current distribution system: the grid.

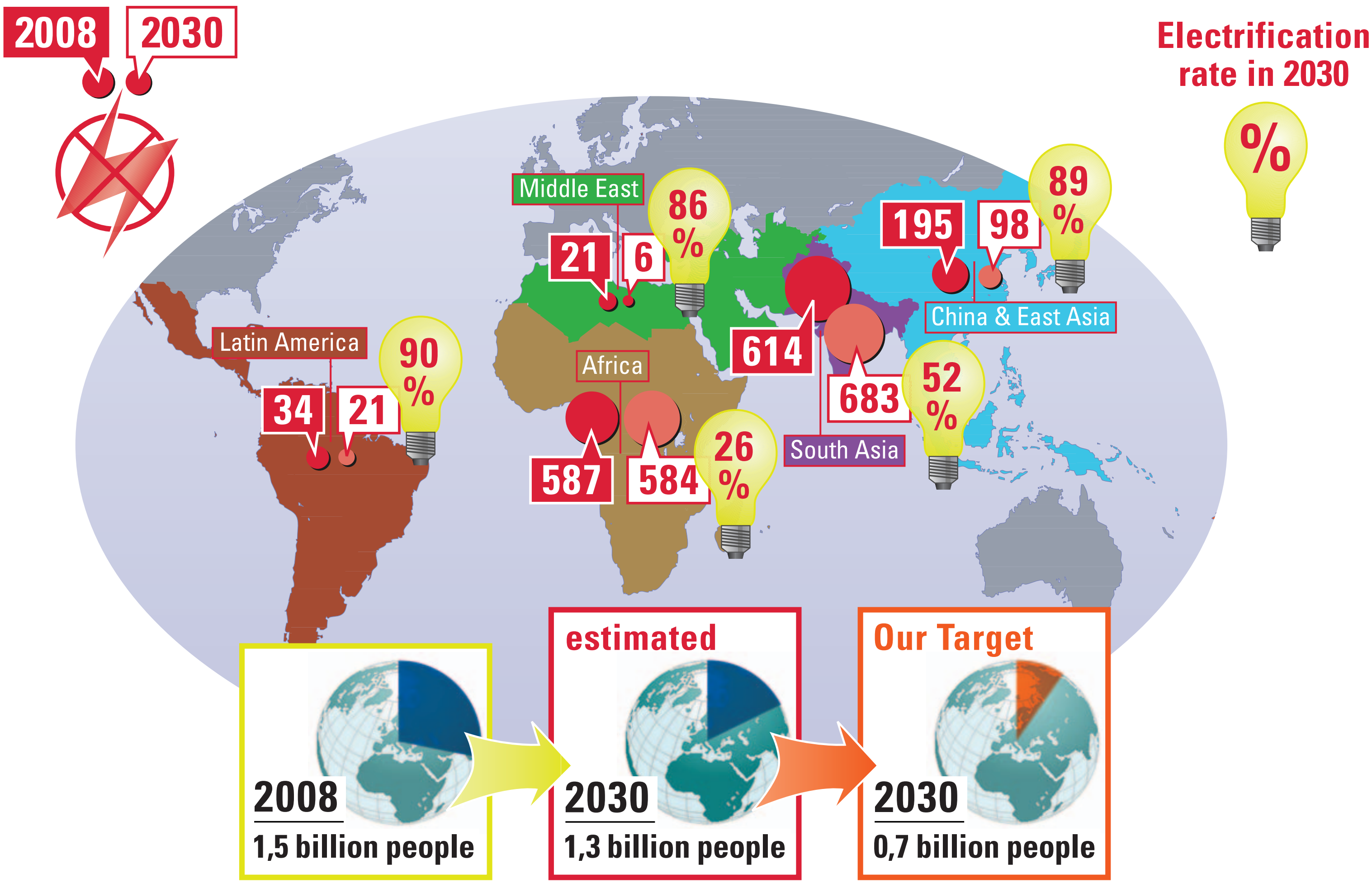
So what did the concerned citizen do?
Walk away, heading home.
Not a bad decision at that time.

Electricity – not for All

South Asia currently accounts for 42 percent of the total number of people in the world without access to electricity, even though the percentage of the population with access to electricity in South Asia increased by around 8 percent over the last three years. Bangladesh, India and Pakistan in total have 570 million people without electricity, 92 percent of whom live in rural areas. In Sub-Saharan Africa only 29 percent of the population has access to electricity today. Despite slightly increasing electrification rates, the total number of people in the region without access to electricity has grown by 78 million since 2001 – mainly due to rapid population growth, which has outpaced electrification.

Source: http://www.iea.org/weo/electricity.asp

Impressions from India in 2008.
Over 600 million people are living in South Asia in similar conditions. Children are born and raised, families with up to four generations nurtured, jobs created and descended, hopes raised and hopes definitely lost.
A situation very hard to imagine by people from the western world. And yet they are there, even increasing, not only in numbers but in individual fates.



Data Source: OECD / IEA. World Energy Outlook 2009. International Energy Agency. Paris, France 2009

Figure 2.5

Population without Access to Electricity (million) in 2008 and 2030* (*estimated)

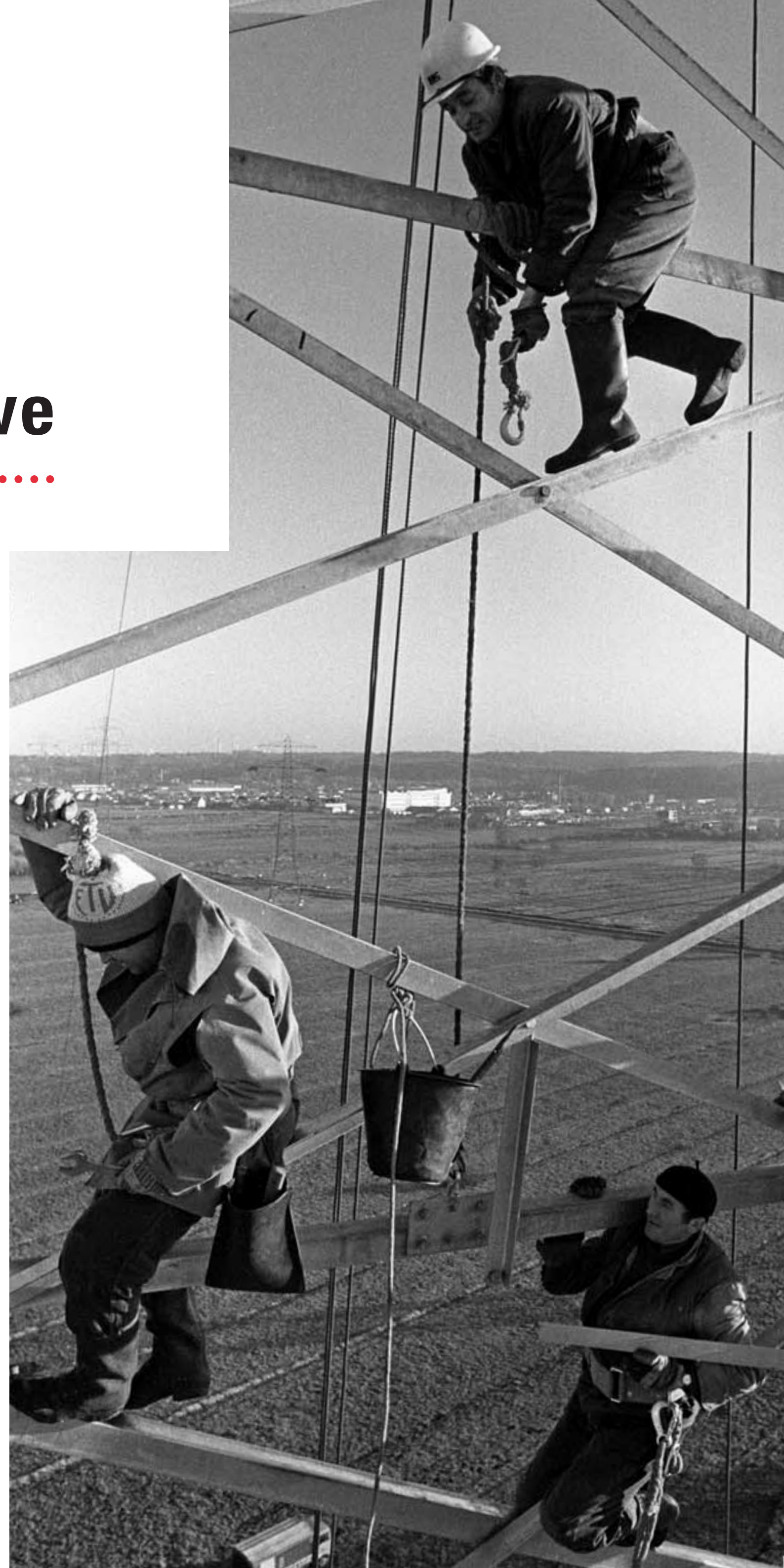
3

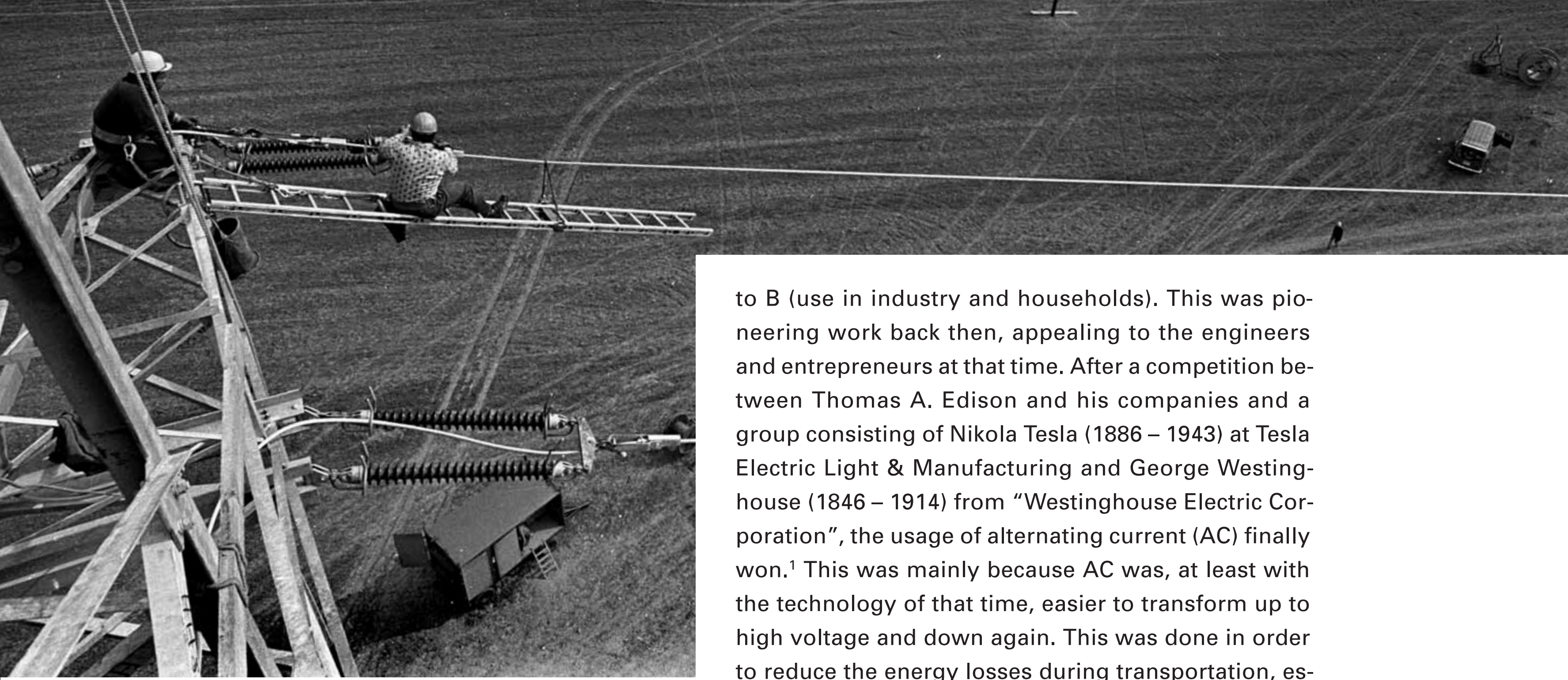
The Grid:
A Matter of Perspective

Today's global high voltage electricity network is a grid in which electricity moves in one direction from suppliers (mostly centralised power plants) to customers. It is accused of being inefficient, and there are calls that it should be promptly updated to become "smarter". This is a worldwide initiative that is currently being heavily funded by governments as a way of addressing energy independence, global warming and emergency resilience issues. To understand the development of our existing grid, one has to look back in history.

The Grid:
A Matter of Perspective

During the initial years of electricity distribution, direct current (DC) was launched into commercial use by Thomas A. Edison (1847 – 1931) "The Wizard of Menlo Park" and first adopted in Manhattan, New York, where it became the standard for electricity in the United States. The beginning of industrialization saw increasing power consumption at huge sawmills and later steel- and aluminum factories or in textile and car manufacturing sites, and meant that in nearly all cases it was not possible to produce electricity were it was needed most. All the growing mega cities did not really allow for building huge DC electricity plants downtown or within the developing areas. Some are now museums or living quarters, like Bankside Power Station at the River Themse in London, which is now the famous Tate Modern Museum, visited by more than 30 million people since 2000.

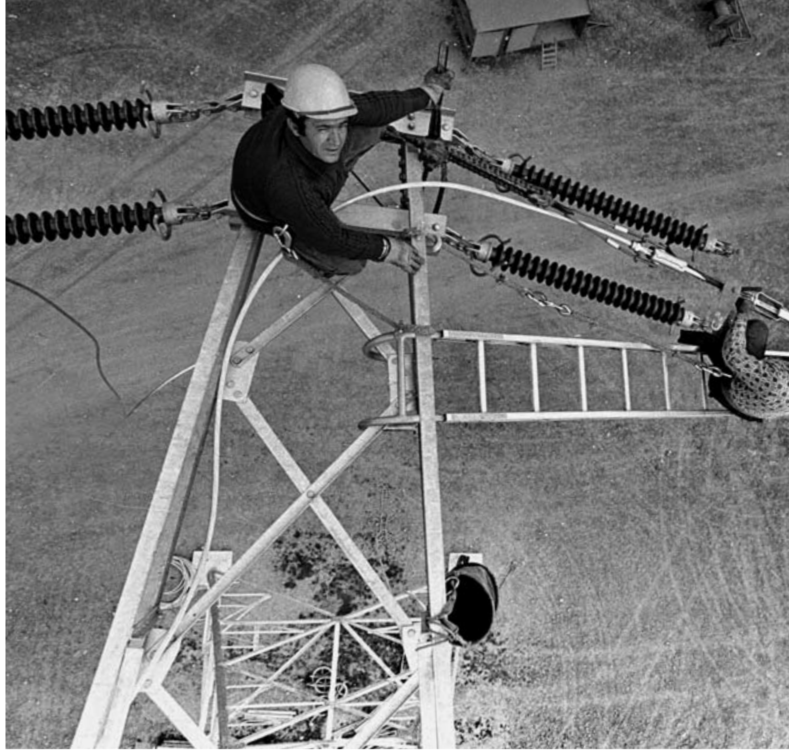




A similar development was seen in Germany; here the first hydro power plant was connected in 1891 over a distance of 175 km (110 miles) from Lauffen to Frankfurt/Main to light the World Exhibition there. Later, steam power plants laid the foundation of our existing electricity system, connecting turbines, generators and transformers (see chapter 2. Turning on the light: The Process of Electricity Generation).

Somehow the electricity had to meander its way through to come from A (production in the power plants) to B (use in industry and households). This was pioneering work back then, appealing to the engineers and entrepreneurs at that time. After a competition between Thomas A. Edison and his companies and a group consisting of Nikola Tesla (1886 – 1943) at Tesla Electric Light & Manufacturing and George Westinghouse (1846 – 1914) from "Westinghouse Electric Corporation", the usage of alternating current (AC) finally won.[1] This was mainly because AC was, at least with the technology of that time, easier to transform up to high voltage and down again. This was done in order to reduce the energy losses during transportation, especially over long distances. This was the state of the art way back, one and a half centuries ago. Today, under current conditions and with knowledge of new technologies the decisions to use AC may have been made differently. Especially when one considers that the power losses are estimated to be about 7 percent of the electricity supplied to the grid. But the grid is now in place and working, so why change it? As long as the primary energies used (mostly coal) are as cheap as they are, there was and is no reason to change the supply infrastructure.

1) http://en.wikipedia.org/wiki/War_of_Currents

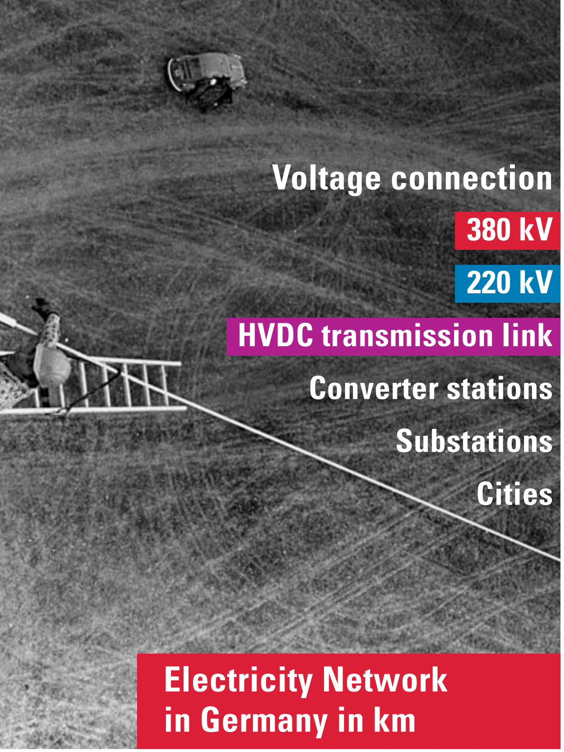


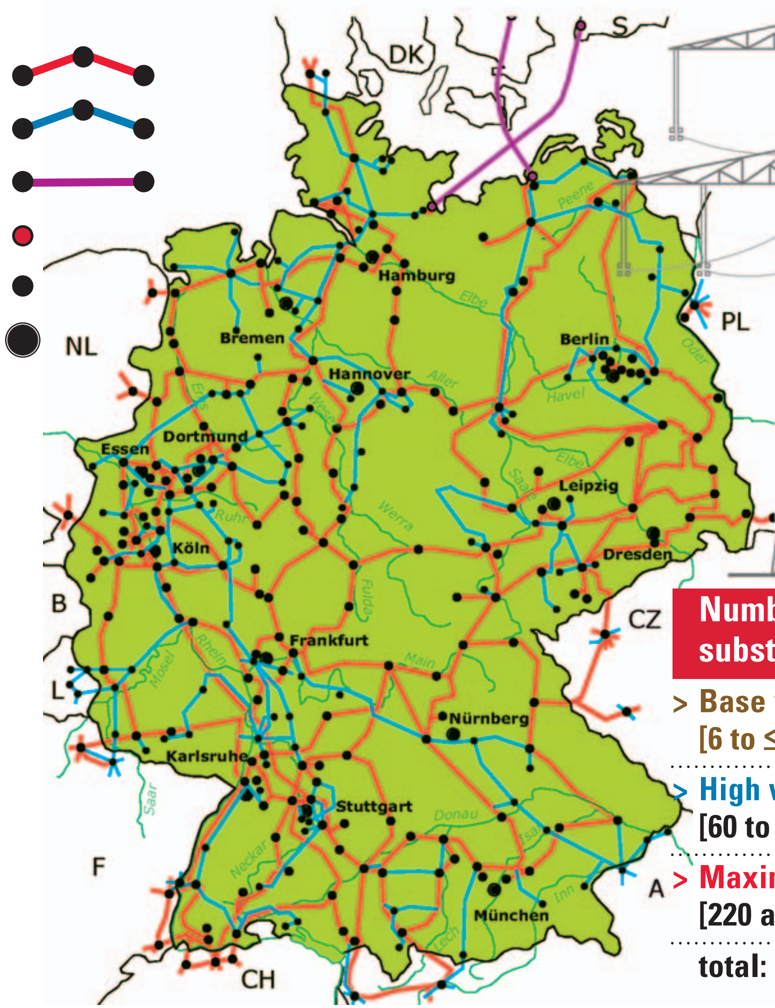
Basically since the late 1880s we transform electricity in transformers at substations to voltages between 15 kV (introduced in Germany in 1891) to 110 kV (introduced in Germany in 1912), later to 220 kV (introduced in the USA in 1924) to 380 kV (introduced in Germany 1957) to 500 kV (introduced in USA and former USSR in 1963) and finally up to 735 kV (introduced in Canada in 1956).[2] The latest trend is to implement high voltage direct current long distance lines (HVDC). Some of them are in daily use in India, China, and Europe already, and are planned for the DESERTEC project between North Africa and Europe in 2015 or later.

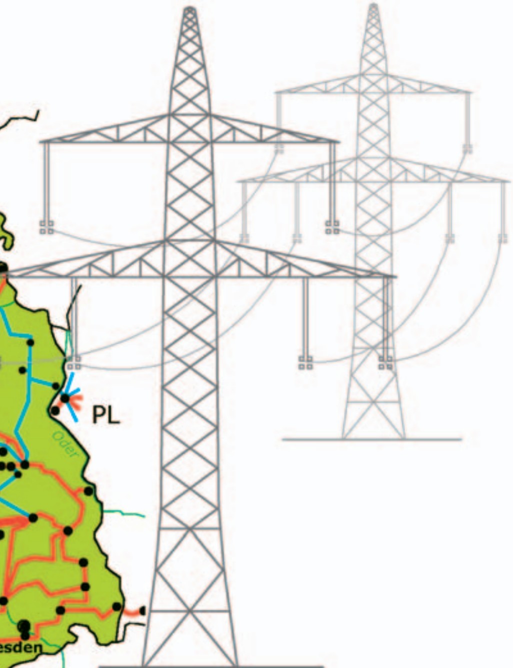
But let's go back to Germany, a relative small country, stretching around 1,000 km (620 miles) from north to south and around 600 km (370 miles) from east to west. At the moment, as a result of the historical development briefly explained above, electricity is carried from the power plants through a transmission network of high voltage lines at 220 kV and 380 kV to substations, where the voltage is then stepped-down to 110 kV for load points (localities, industrial areas, villages, etc.) or to 20 kV (base voltage) for industries or further distribution to low voltage lines (Figure 3.1). Here additional transformers are again used to step the voltage down to 0.4 kV for distribution to commercial and residential users.

Sadly enough, these voltage lines run for thousands of kilometres. In Germany this network consists of almost 1.67 million kilometres (1 million miles) of transmission lines. 94 percent of them are dedicated to the transmission of low voltage (0.4 kV). 566,300 transformers/substations are used to step up and down the voltage, 98 percent of them for the base voltage network.

2) Heuck, Klaus et al. Elektrische Energieversorgung. Vieweg Verlag 1984. page 3







Electricity Network in Germany in km

> Low voltage [0,4 Kilovolt]	1.070.000
> Base voltage [6 to ≤ 60 Kilovolt]	494.000
> High voltage [60 to < 220 Kilovolt]	74.700
> Maximum voltage [220 and 380 Kilovolt]	36.000
total:	1.674.700

Numbers of substations/transformers*

*estimated

> Base voltage [6 to ≤ 60 Kilovolt]	557.700
> High voltage [60 to < 220 Kilovolt]	7.500
> Maximum voltage [220 and 380 Kilovolt]	1.100
total:	566.300

Data Source: Verband der Netzbetreiber (VDN). Deutsches Höchstspannungsnetz. Berlin, Germany 2006

Figure 3.1

German High Voltage Network

When you look at the map of Germany, you can hardly image that literally 1.000 power lines are running in parallel both in north-south and east-west direction. All this effort, just to bring electricity to industry, commerce, and small and medium enterprises; not to mention the plugs in your homes or apartments. The actual problem lies in the order of magnitude and the rather antique nature of the global grid and its infrastructure, as it exists today. In most cases, the lines are old; some of them tend to fail during snowstorms in Winter. Some substations and their transformers date back to the 1940's. Sometimes it is like a miracle that it all is actually still running. Just ask insiders of this system and they will tell you how lucky they sometimes are to overcome their day or night shift without remarkable failures. When comparing this to the grid in the US or in China, or in India it is even more complicated. The confidence, however, that pervades the views of our utilities, grid operators and governments in our centralized energy system is startling. Just look at the next page to find the U.S. Department of Energy's (DOE) definition of the electricity grid, which they wrote after the failure of the U.S. power grid at the east coast in August 2003.

At this point we have arrived at an impasse, where we spend too much time trying to keep an infrastructure which actually changed little since Thomas A. Edison switched on his first electric illuminating system on September 4, 1882.[3] There's no particularly urgency to move things along, since each of us has all the (cheap) electricity he or she needs, although there are promising proposals for a resolution.

Countries around the world are just starting to integrate advanced technologies that will help to build a more efficient and more resilient electrical grid, in short: to make it "smarter".

3) http://www.coned.com/history/electricity.asp

The Grid

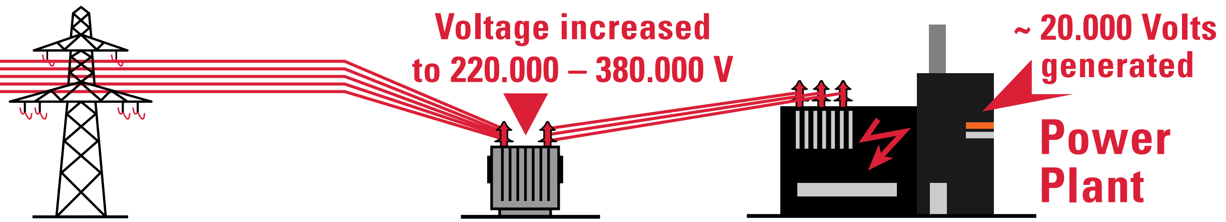
... as described by the U.S. Department of Energy in 2004

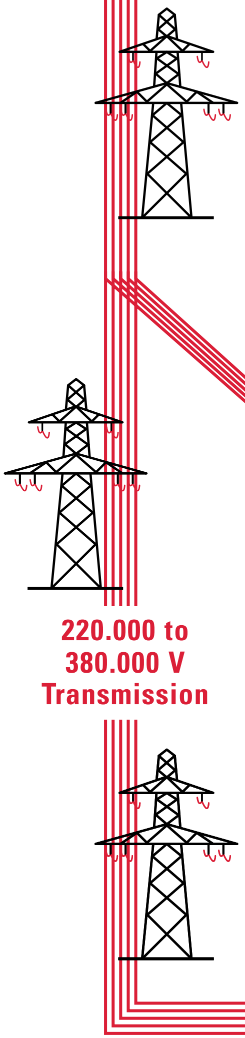
The power system is an engineering wonder. Every second of every day, power generators produce exactly the amount of electricity that consumers require when they turn on lights. With a minuscule amount of storage on the system, electric utilities and grid operators continuously perform a complicated balancing act. Grid operators schedule power flows across transmission lines to meet the supply and demand of the market.

Worldwide, there are 50.000 large and small generating stations. Most of them are connected in regions, states, countries or even continents like Europe electrically and are spinning in perfect unison. They generate electricity, which is transformed up and down in different steps to provide consumers with 120 V at 60 Hz (Europe, Asia: 230 Volts and 50 Hz).

Large customers in industry receive higher voltage due to their higher consumption. Any deviation from this combined balance can cause grid instability that could damage power plant and transmission equipment. Obtaining custom-built replacement parts for some of this equipment, such as large steam or generating turbines, can take months or longer. Damage occurs very quickly, and all this equipment is expensive, so complex computer and management systems are in place to guard against failure. The primary protections are breaker switches that switch the line off automatically if electrical parameters such as frequency or voltage stray outside narrow boundaries. Electric power grid operators manage all of this by calling for power plants to come on-line and cycle off to meet the ebb and flow of demand. They also direct traffic on the transmission system for a specific territory. Their work is much like that of air traffic controllers, who are bombarded with data and must make quick decisions based on computer simulations and their understanding of the system. In a nutshell, their job is to detect the conditions that cause blackouts, implement steps to avoid them, and restore normal operations as soon as possible. In regions that have them, regional transmission organizations provide input to system operators about conditions outside their control areas that might affect operations.

Data Source: http://www.doe.energy.gov/smartgrid.htm





The concept of a smart grid is to deliver electricity from suppliers to consumers using two-way digital technology to control appliances at consumers' homes to save energy, reduce cost, and increase reliability and

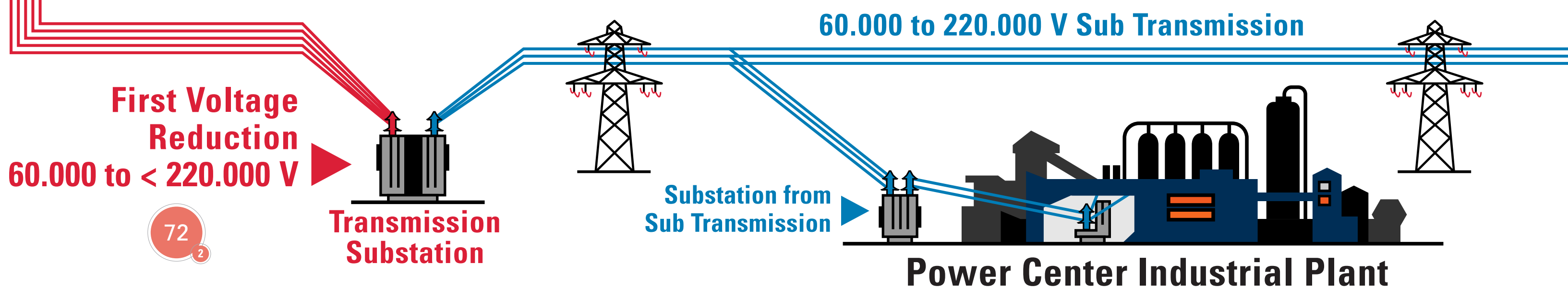
transparency.[4] Utilities would be able to easily rig some of their customers appliances to cut power consumption during periods of high demand or supply drop-offs, e.g. adjusting electronic thermostats or shut off of electric water heaters. The American government alone wants to spend US$ 3.4 billion to modernize its electric grid and therewith open a new chapter in the quest for sustainability.[5] The US$ 3.4 billion in federal money will be matched by contributions from private companies, resulting in a total grid-improvement package estimated to be about US$ 8 billion.

In Germany, policies and programs using smart grid technologies continue to emerge and progress. However, the question of who is going to pay for that upgrade in Germany remains open. It looks as if the grids will be unbundled first from their current owners. The majority of the German high voltage network today belongs to only four German utilities: EnBW, E.ON, RWE, and Vattenfall. These companies have staked their claim long time ago. They are also responsible for the production of electricity in their own power plants, as well as for its distribution, and have the connections to the customers in sales and services. This is a rather comfortable position to be in. Only a few municipal energy suppliers (Stadtwerke) are also owners of the grid in their local community in Germany. The trend towards municipal suppliers, however, has been increasing over the past years.

Another challenge lies in the integration of electricity created by renewable energies like wind, concentrated solar power, photovoltaic and hydro. Although the installation of wind farms and/or new hydro power

A typical Electric

The voltages vary from



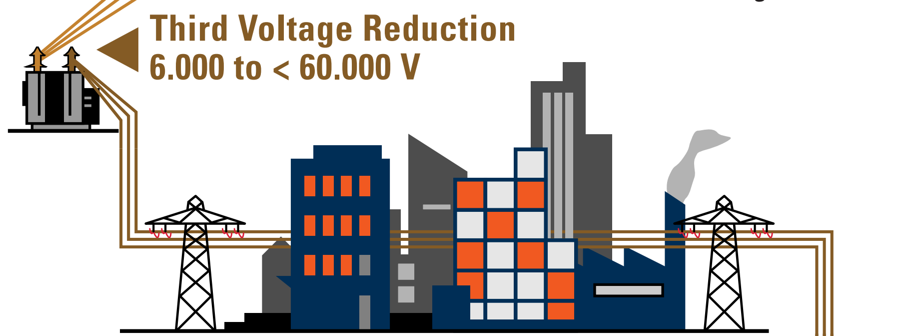


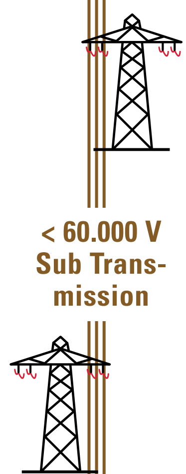
Figure 3.2

Supply System
country to country

stations is not at all new, the existing grid is not particularly suited to those fluctuating power sources. However, the often cited disadvantages from – let us say - wind energy could be easily turned into advantages through clever supply and demand management.

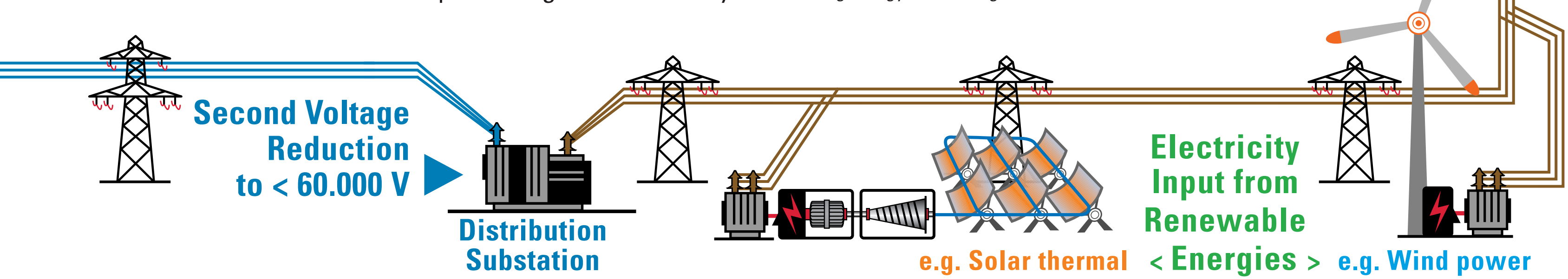
Today, the peaks created in wind farms are simply seen as “unwanted surpluses” instead of being used as a commercial good. In many cases, wind parks have to be shut down by the ruling utilities, as they cannot handle the electricity generated by them at a given time. In another case, power production from other sources, particularly from natural gas plants with quick start times, are used during times of sudden calm. Are we in a position to afford this kind of behaviour? I do not think so. Eventually there should be smarter solutions.

In the end, the consumer has to pay for the transformation of the existing, rather unintelligent grid to a smart one, regardless by whom the upgrade will eventually be done. And it must be done. But what about renewable energies? Is it sensible to build even more transmission lines that transport the “green” electricity from remote areas, where it is likely to be generated, to centres of population? Are there alternatives? I think there are. We can use renewable energy directly off-grid or with mini-grid access. Or we could use hydrogen as a completely new energy carrier to replace the grid as a whole. In any case, it is more a question of attitude, not to mention of morals, to consider our method of power transmission and distribution. It is not a question of money nor a question of resources nor a question of technology. It is a question of common sense.



4) http://en.wikipedia.org/wiki/Smart_grid

5) http://www.whitehouse.gov/blog/2009/10/27/smart-grid-creating-jobs-saving-energy-and-cutting-electric-bills



4

Consumer Electronics:
A Spoonful of Ingenuity

Over and over again, industry and politics make us believe that the problem for emerging technologies in conquering the market, especially in the field of renewable energies, is that the supporting infrastructure is not generally available. But the problem as such may also lie in policy frameworks where policies including investment tax credits, renewable portfolio standards, feed-in tariffs as well as various research and development (R & D) support schemes are applied. Sounds complicated and inflexible? Well, indeed it is.

Evolution of the Apple iPod

The Apple iPod revolution that began in 2001 not only overturned the conventional way of listening to music, but affected people's entire lives. On October 21, 2001 Apple Computer, Inc. from Cupertino, CA, USA, introduced its first 5 GB hard-drive based MP3 player storing 1,000 songs with a battery life of ten hours and a sales price tag of US$ 399. A simple-but-elegant concept was born out of a tiny hard drive that Toshiba had developed at that time but did not have a clear market for.

Only nine years after the introduction of its iPods, Apple produced and sold over 21 million units during the fourth quarter of 2009 (Christmas time) alone (Figure 4.1): That's around 234,000 iPods per day, approximately 9,722 per hour or 162 devices per minute. The logistics behind these numbers in manufacturing, quality assurance, sales and cost management as well as revenue handling, is hard to imagine, specially for those who are thinking more in decades.

The iPods from Apple are a series of portable, so-called "Portable Media Player". The MP3 format was developed in the 1980s by a German group led by Karl Heinz Brandenburg of the Fraunhofer Institute for Integrated Circuits (IIS) in Erlangen, Germany and by the Friedrich-Alexander University Erlangen in cooperation with AT & T Bell Labs and Technicolor SA, formerly Thomson SA. The Fraunhofer Gesellschaft (FhG), based in Munich, Germany, owns patents on parts of the software which is used in the MPEG encoding. Since September 1998 FhG and Technicolor are collecting royalties for the use of the MP3 format in electronic music distribution, broadcasting and streaming.

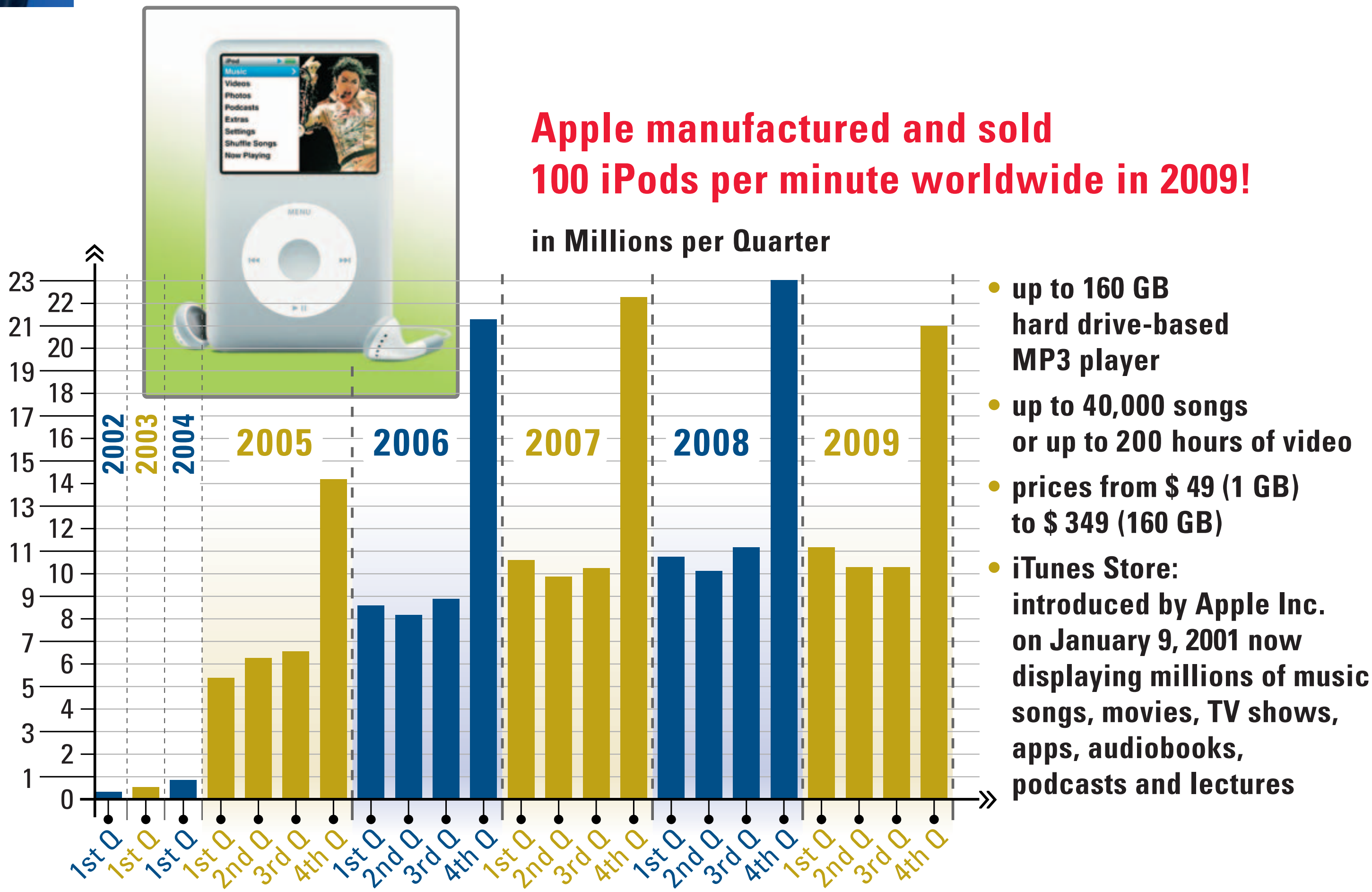
Traditional thinking warns us that there are many reasons to believe the price of US$ 399 for such a portable device about the size of a cigarette pack might be too high (and not surprisingly, only 400,000 units were sold in the first fiscal year). The nice thing about the Apple iPod, however, is that increasingly more value through superior quality and advanced features has been added with each successive generation. The sixth generation of iPods, introduced on the market in 2008, for example, features a 160 GB hard drive storing up to 40,000 songs, 200 hours of video or 25,000 photos with a battery life of up to 36 hours.

The iPod is, by default, only delivered with minimal equipment. This has triggered the development of a third-party industry of iPod accessories, made by different manufacturers worldwide, mostly based in China where iPods are produced. (In fact, on every one of Apple's products, you will find a slogan, unthinkable a few years ago: "Designed by Apple in California. Assembled in China"). The accessories themselves are not a low budget solution, but easy to handle and high in quality.

The rechargeable batteries built into the iPods are based on lithium and are usually charged via a USB cable directly from a computer. That means that in the normal configuration, no charging unit is included. If you want one, you have to buy one separately. The maximum battery life, according to official Apple figures, is currently up to 36 hours (for the 160 GB iPod Classic). Changing internal batteries by the user is not supported or intended by Apple.

In addition to the sale of Apple iPod hardware, the company also developed another brilliant business idea, which generates billions of US$ and a permanent revenue flow on top of the sales of the hardware for them: With Apple's own "iTunes Store" one can buy music songs and albums, download or borrow movies, TV shows, listen to podcasts or watch lectures from respected universities and so on. As of January 2010, Apple has sold more than 6 billion iTunes songs, at the minimum price of US$ 0.69, and iPhone and iPod touch customers have downloaded three billion applications, so called apps, in less than 18 months.[1] Payment via credit cards is done in fractions of a second. Apple is providing proper invoices with the correct VAT, all fully automatically, safely and reproducibly 7/24 in all countries with iPod distribution networks. This network was designed and is run by Apple Inc.

1) http://www.apple.com/pr/library/2010/01/05appstore.html



Data Source: Apple Inc., Investor Relations, http://www.apple.com/investor/

Figure 4.1

Evolution of the Apple iPod 2002 – 2009

As seen in the Figure 4.1, iPhone's sales are slowly decreasing compared with the fiscal year 2008 to 2009. Does that affect Apples business? Not really, as they keep inventing new product lines. One example is the iPhone, a fashionable cellular phone with features that one could only have dreamt of just a few years ago. This product offers either free of charge or for prices between US$ 0.99 to 29.99 the download of personal apps. Among these apps are helpful tools to guide you through unknown territories of the world (Google Earth) or to introduce you to the theoretical subjects for the JAR-Commercial Pilots License for Airplanes (Aircraft General Knowledge).

These apps, enabled by Apple, have again created a new market, the distinctive feature of which is characterized by its open source architecture. This open source approach has motivated thousands of creative programmers all over the world to think of new apps, enriching the spectrum and even earning money with the implementation of their new ideas. They simply upload their apps programs to Apple, who hosts them online for owners of the iPhone to download. The originators of the Apple apps regard their work as a contribution to the commons rather than a way to increase their profit margin. This is in stark contrast to the more governmental funded progress!

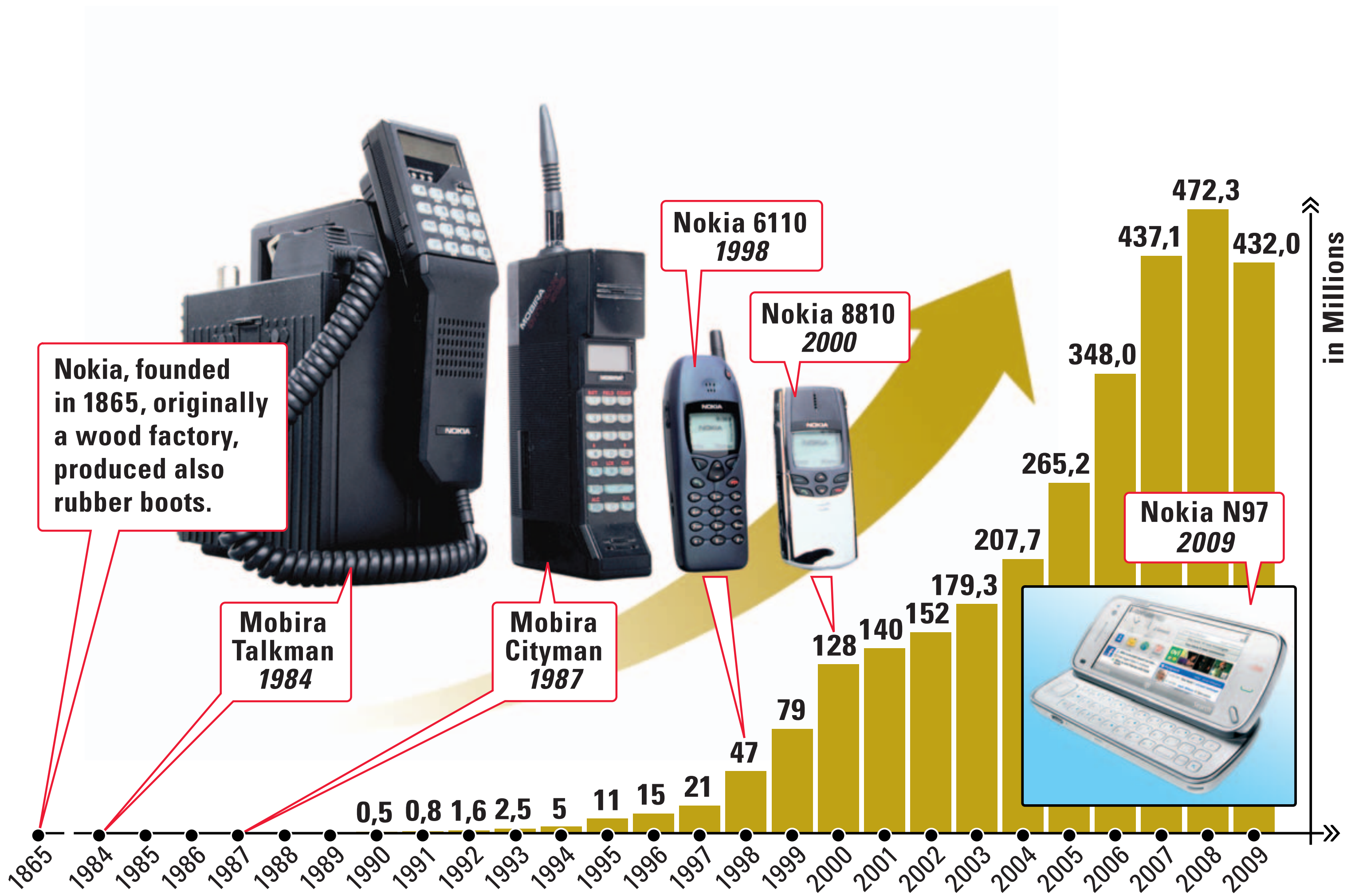
While writing this book, Apple introduced its iPad, a tablet-computer which combines a cellular phone and laptop with a large touch screen that can also be used to read books on- and offline. The first version will go on sale in April 2010 and is priced from US$ 499 for WiFi-only editions with the least storage capacity to US$ 829 for 3G connectivity. Apple's profit margins for the iPads have been pegged at between 30 and 50 percent. Also the electronic books which will be available in the iBookstore are expected to be higher than the US$ 9.99 set by Amazon for its Kindle e-reader. Maybe this book once will not even have a printed edition any more. Why not?

From Me to You:
Nokia Mobile Phones

From out of nowhere, the Nokia Corporation, based in Espoo, Finland, has become a pioneer in the telecommunication market. In 2009 alone it sold more than 432 million mobile phones (on average 1.2 million mobile phones per day) and held an estimated 39 percent share of the global device market (Figure 4.2). They have 15 manufacturing plants in nine countries, and they distribute their products in 150 nations. Nokia now has almost 130,000 employees from over 120 countries. How has Nokia reached this leadership on the world market?

As with the Apple iPod, this triumph would have never been achieved through public policy, funding lighthouse projects, or even with a milestone program planning. Nokia, founded in 1865, originally started out as a paper mill, producing rubber boots from 1898 onwards. The sale of mobile phones began in 1984. First figures were released starting in 1990 (500,000 units sold per year). Since then, with annual growth rates of up to 123 percent per annum (1997 to 1998), Nokia was on its way to worldwide market leadership in mobile phones, a position which this company is still currently holding in 2010.

One might think that here is a simple story of the right market at the right time. But developing the right products is no simple task. To keep its customers coming back regulary, Nokia offers unique product designs and technologies that continue to give them an edge over competitors. Their latest market is Africa, where they offer new services like remote phone stations, hosted by entrepeneurs, who sell the use of their Nokia celluar to local residents, who sometimes travel long distances for just one phone call. Only with good management, excellent employees (who are most welcome



Data Source: Nokia Corp., Company Information, http://www.nokia.com/about-nokia

Figure 4.2

Nokia Mobile Phone Sales 1984 – 2009

to bring in their own ideas), clever distriubuted manufacturing, exceptional quality assurance, powerful logistics, remarkable marketing and a strong distribution system can a company motivate millions of customers from around the globe to buy their products at relatively high prices. A multidisciplinary design team of about 250 psychologists, market researchers, anthropologists and technology specialists from 25 nations are examining exactly how people are using telecommunication technology in their everyday lives. The personification of the products plays an important role as well. According to figures released in March 2009, Nokia spent about EUR 6.0 billion p.a. on R & D with nearly 40,000 experts working in this specific area (approximately 31 percent of Nokia's workforce, including Nokia Siemens Networks) in 2008.[2]

Nokia's first transportable phone, the Mobira Talkman, launched in 1984, weighed 5 kg, and was quite bulky, and thus often installed in cars. In 1987, however, Nokia introduced its first handheld phone, the Mobira Cityman, weighing "only" 800 grams with its battery. The cost of a Mobira Cityman back in 1987 was approximately EUR 4,560. These new cellular phones were, at that time, of course only affordable for the wealthy, such as bankers, celebrities or CEO's of listed companies. Only later, by introducing other models, could the demand increase, driving production up and prices down. Better known as the concept of a "learning curve", which applies to nearly all other industries, like the aircraft industry, were I originally come from (see chapter 7.1 A Question of Design).

On the surface, a sustainable society does not need more proposals to become real; policy support and political pressure are sometimes helpful but not enough. New and more original ways of thinking, supplemented by enthusiasm and courage, are needed as we move toward sustainability. More so because all the modern portable amenities that we are surrounded by and use on a daily basis use batteries. While this is very convenient for most of us, it has led to some issues that many people do not think about and which will be explained in the following chapter.

2) http://www.nokia.com/NOKIA_COM_1/About_Nokia/Sidebars_new_concept/Nokia_in_brief/InBrief_08.pdf

The Contradiction between Theory and Practice

At this point I dare to ask: Could this personalized approach successfully being introduced by Apple and Nokia also be a model to introduce hydrogen and fuel cells into the market? Is everything that we are currently doing in research work and developing H_2/FC products for the market being done too much "under cover"?

Should we not be much more open with our knowledge and, even further, with the lessons learned? Should we carry on working on low budget products when we try to implement hydrogen and fuel cells? I think we should stop these attempts. Maybe, with a more transparent approach, we could be much more successful in turning the vision of a Hydrogen Society into reality. And as another benefit: We would save time with a more open attitude.

The other aspect these two success stories are leading us to is that both companies, Apple and Nokia, had the strength to introduce new products which were also connected to new services. Services, which fulfilled the desire of people, also motivated their desire to buy the products. Both companies became world market leaders with their new lines of products in a very short time, and have maintained their positions for a long time. We should consider these examples, and learn from them.

We must be aware that the momentum in our example was not triggered by governmental support or public funding. The reason why this type of support will not lead to market share is easy: How could civil servants or employees of organizations or associations ever know how future market needs will look like? How can they define design-targets for unknown fields? I am afraid to say that from this corner we should not expect much. There will, in the future, be other ways to conquer global markets for hydrogen and fuel cells applications. But one thing is for sure: these ways will not come on their own, and will only be achieved through hard work.

Where has all the Power Gone:
Daily Energy Losses

We all know them, although they are rather inconspicuous. There are many of them in every household of the "Western" world, which in this case also includes developed Asia. And even in Africa they can now be found in the millions. They are mostly plain, except for the "Made in China" sticker, and a little green LED. We know them as external chargers for batteries in cellular phones, laptops, cameras, navigation devices, game consoles, MP3 players, and electronic weather stations. Monitors, flat screens, and printers do not work without them. But nobody talks about them, because they simply "are there and function". And nobody realizes how energy-consuming they in fact are. We are talking about AC/DC converters. In every office there are between 10 and 20 of such adapters, depending on how you count them. In households with children you can easily count 20 to 50 of such devices. With every new electrical gimmick, a new AC/DC adapter tags along. What happens with the old ones? Just look in your bottom drawer to find them. All these innocent looking units have only one function: To transform the existing AC electricity of 220 V, 50 Hz (Europe and Asia) or 110 V, 60 Hz (US) to low voltage DC. As a by-product, a large fraction of the electricity is transformed into heat. You might as well call them electric heaters. The question is: Is this worldwide overwhelming application of power conversion worth its price? For the utilities it certainly is. Because they are billing us every Watt-second we are using from the moment we plug in the AC/DC converters. For consumers, the next generation, and the environment – rather not. Nobody in the world is discussing these, in my opinion, rather important questions, considering the order of

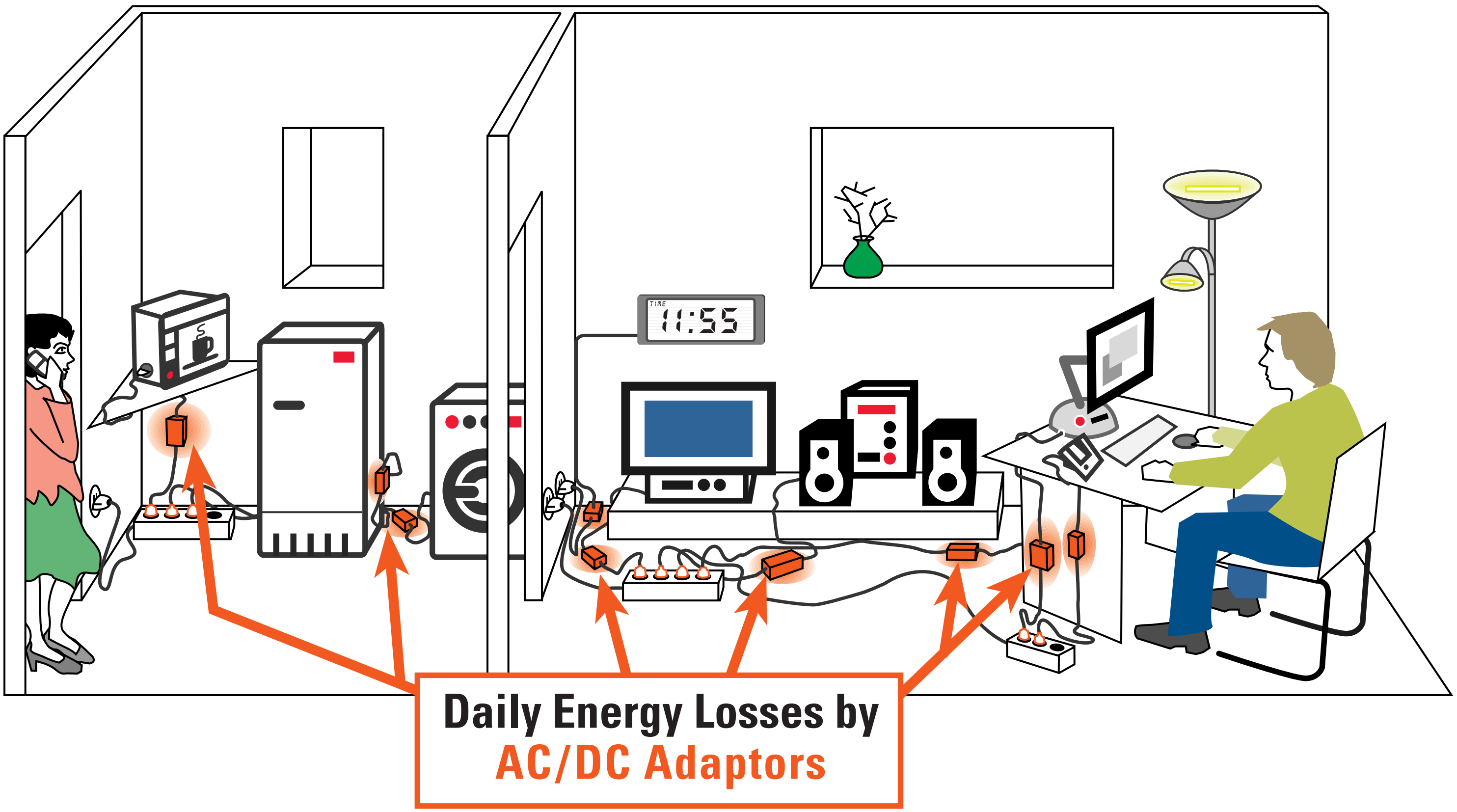
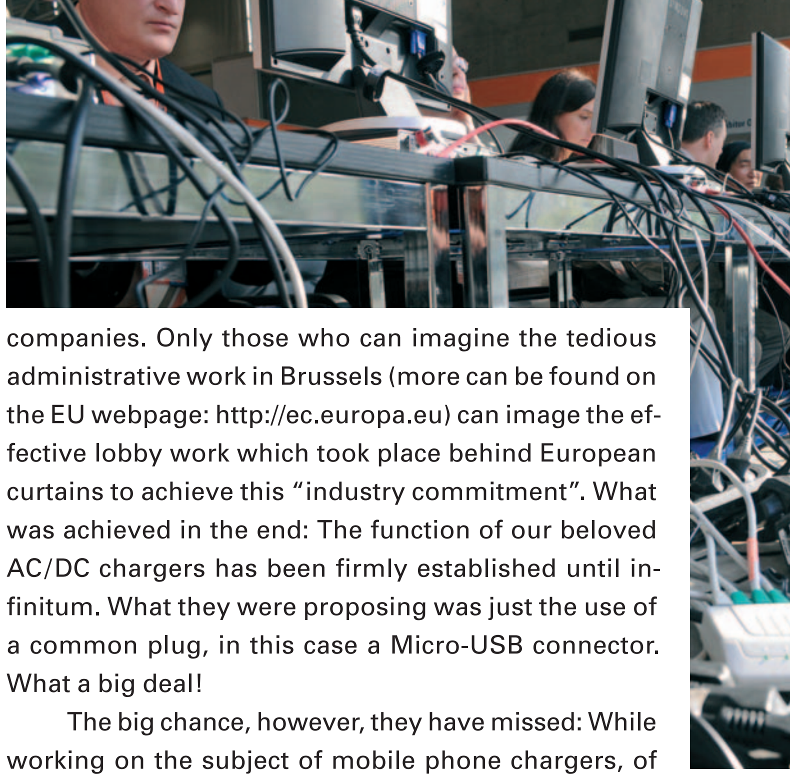


Figure 4.3

Daily Energy Losses by AC/DC Adaptors



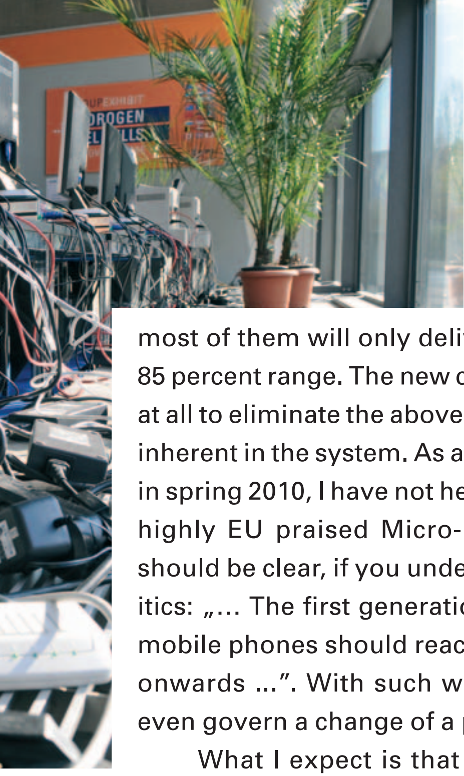
magnitude of the daily distribution, usage, and ever increasing numbers of these units. In the year 2009, for example, more than 1.21 billion new mobile phones were sold worldwide[3] and ALL of them were equipped with a new AC/DC converter to charge their batteries. That means there are 1.21 billion of them around, only from the new cellular phones, sold in only one year. And to make things worse, they vary from model to model, and are thus not even compatible with each other.

Actually, there was an attempt from the European Commission in 2009 to change this attitude:[4] „... Incompatibility of chargers for mobile phones is a major inconvenience for users and also leads to unnecessary waste. Therefore, the European Commission has requested industry to come forward with a voluntary commitment to solve this problem. ... As a result, major producers of mobile phones have agreed to harmonize chargers in the EU. … the industry commits to provide chargers compatibility on the basis of the Micro-USB connector. ... The first generation of new inter-chargeable mobile phones should reach the EU market from 2010 onwards ...”. This agreement was signed by representatives from 13 well known consumer electronics companies. Only those who can imagine the tedious administrative work in Brussels (more can be found on the EU webpage: http://ec.europa.eu) can image the effective lobby work which took place behind European curtains to achieve this “industry commitment”. What was achieved in the end: The function of our beloved AC/DC chargers has been firmly established until infinitum. What they were proposing was just the use of a common plug, in this case a Micro-USB connector. What a big deal!

The big chance, however, they have missed: While working on the subject of mobile phone chargers, of which Nokia alone was distributing more than 440 million units in 2009, the EU could make a realistic cost-benefit-analysis considering environmental externalities. In this case they would have easily found that the existing AC/DC chargers are only wasting our limited resources because they have to rely on an old-fashioned process of electricity production and transformation, and, in most cases also rely on an antique grid network. It seems not to be of much interest how much AC power these devices ultimately use to convert the electricity into the DC power needed by most appliances. In fact,

3) http://www.gartner.com/it/page.jsp?id=1306513

4) http://ec.europa.eu/enterprise/newsroom/cf/itemlongdetail.cfm?item_id=3241



We are no exception:
Exhibitors lounge at
the HANNOVER FAIR 2009;
AC/DC converters
everywhere.

most of them will only deliver efficiencies in the 80 to 85 percent range. The new common plug does not help at all to eliminate the above described losses which are inherent in the system. As an aside, in writing this book in spring 2010, I have not heard or seen anything of the highly EU praised Micro-USB connectors. But this should be clear, if you understand the language of politics: „… The first generation of new inter-chargeable mobile phones should reach the EU market from 2010 onwards ...”. With such weak phrasings you cannot even govern a change of a plug.

What I expect is that another device will come sooner than the common plug, because it is more attractive to users: That is a wireless charging unit. Here, power will be transferred from the charging unit to the devices with magnetic induction technology. This is also not at all new. You may recognize this technology from your electric toothbrush. What is new, though, are the required standard specifications to bring compatible products to market. These are being worked on by the Wireless Power Consortium which is represented by 27 members from consumer and communication industry.[5] Not a solution to the fundamental problem either, but certainly more practical than carrying around long cables.

So what is to be done? How do you boycott such a wide-spread device? Well, you could refuse virtually every device that contains any kind of digital electronics. A better alternative may be to substitute DC power as a replacement for conventional AC power and thus skipping the whole power conversion process. The rapidly discharge of DC by resistance along transmission lines has long been overcome; however, there is still reluctance within the industry to switch to it. It seems that as long as electricity remains cheap, the inefficiency of every AC/DC converter can be easily afforded. But, as far as I am concerned, if DC is what we actually want, we should generate and use it directly at our homes and offices – without depending on the utilities, their grid and the transformation processes.

Fuel cells powered by hydrogen have the potential to do this job and thus end our reliance on global oil companies and utilities. But before we successfully transform ourselves to a new society powered by hydrogen, we need to know the rules by which the most common element in the universe plays.

5) Arlt, Bodo. Bodo’s Power Systems. Laboe, Germany 02/2010. page 18f.


5

Up, Up and Away: The Making of Hydrogen

On the threshold of the twentieth century, aviation conquered the laws of gravity. As this new century unfolds, we venture out to another quest: the production and use of hydrogen on Earth. Gaseous hydrogen with a density of 0.0837 kg/m^2 can hardly be found on our planet. With just seven percent the density of air, it easily escapes from the Earth's gravitational attraction. However, hydrogen does occur on Earth virtually limitlessly: bonded with oxygen in water, and in organic matter such as biomass, coal and natural gas. The hydrogen we use today is extracted from these naturally occurring compounds in a variety of generation processes. But how feasible and affordable is it to produce the hydrogen?

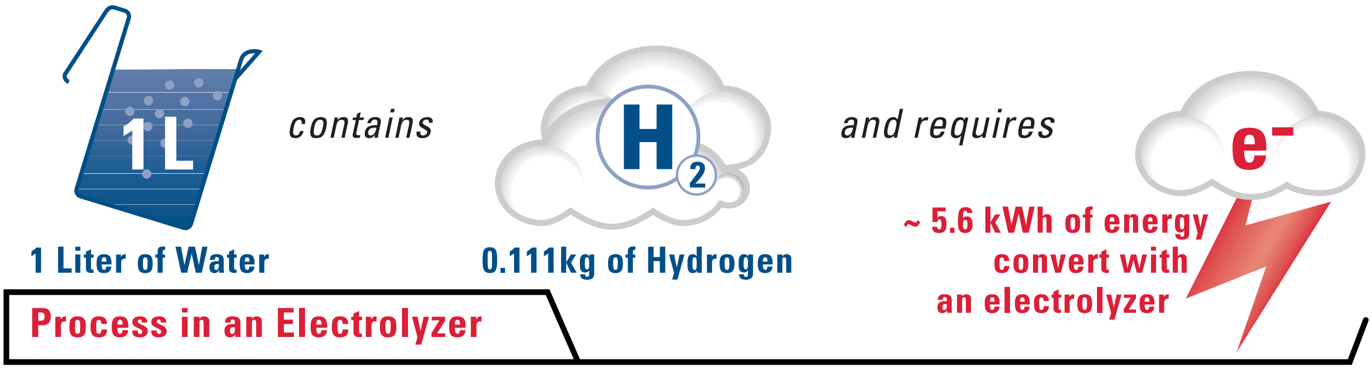
Hydrogen and the Laws of Physics

Hydrogen's atomic structure, consisting of a single proton and a single electron, makes it the lightest and simplest of all chemical elements. It is a colorless, odorless, tasteless gas that has, after helium, the second lowest boiling point, -252.9°C (-423.2°F), and the second lowest freezing point, -259.3°C (-434.7°F), of all elements.

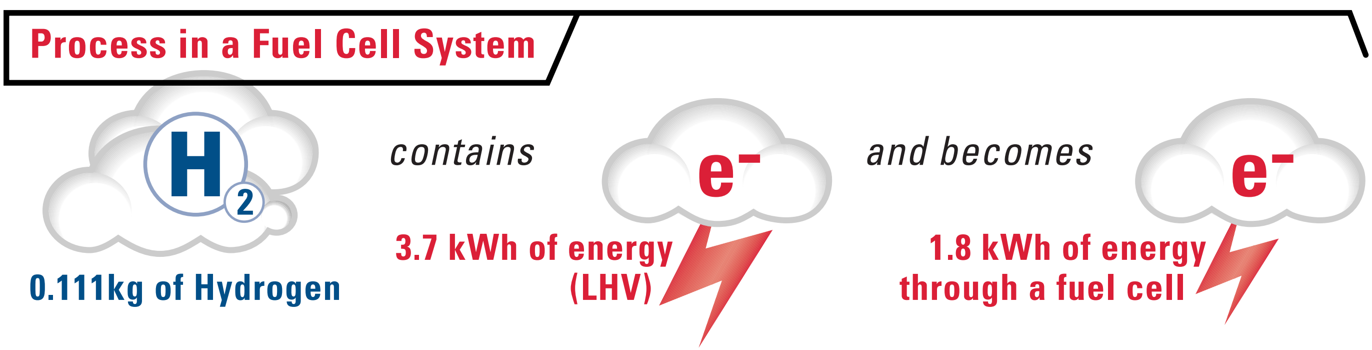
Hydrogen is an energy carrier like electricity, and not a primary source. It must therefore be produced from some other form of energy. These conversion processes are not 100 percent efficient, because some of the energy is always converted into thermal energy which is dissipated to the atmosphere and can no longer be used to perform work. Heat, electricity, or chemical energy can be employed to extract hydrogen from various compounds. But only if renewable energy is used for this purpose, will the resulting hydrogen be a truly clean and green energy carrier. Electrolysis, which uses direct current electricity to separate hydrogen from water, could be a possible technology used to produce hydrogen entirely renewably and without pollution, but it requires the input of large amounts of electrical energy as shown in Figure 5.1. In an ideal system, 3.9 kWh of electricity and 1 liter of pure water are required to produce 0.111 kg of hydrogen. But typical commercial electrolyzer system efficiencies vary between 56 and 73 percent which corresponds to 70.1 to 53.4 kWh/kg[1] or roughly 5.6 kWh for extracting 0.111 kg of hydrogen from 1 liter of water. In these calculations the energy lost to generate the electricity (and to convert it from AC to DC) is not included.

Splitting water into hydrogen and oxygen is reversible, therefore, it is possible to let both gases react and combine to form water using a fuel cell, releasing

1) NREL. Technology Brief: Analysis of Current-Day Commercial Electrolyzers. CO NREL/FS-560-36705. Golden, USA 09/2004



electrical power, and producing only water and heat as a by-product. But there is a catch: 0.111 kg of hydrogen contains only 3.7 kWh of energy which becomes 1.8 kWh of electricity through a fuel cell (which is roughly 50 percent efficient). It is clear that using electricity to split water to form hydrogen and oxygen and then to combine them again to generate electricity seems to be a quite straightforward process. But you cannot break even. The energy required to create hydrogen is always higher compared to the energy you would get when using it. Moreover, if the electricity for the electrolyzer is derived from fossil fuels then there is no advantage over using fossil fuels directly. You still get all the pollution, in addition to a considerable loss of energy inevitably resulting from the laws of thermodynamics. Electrolysis currently supplies roughly 4 percent of the world's hydrogen. But there are other processes that may or may not use electricity as an intermediate form of energy. What about their efficiencies and environmental impacts? Let's have a look!



Data Source: Daryl Wilson, Hydrogenics Corporation, Mississauga, Ontario Canada

Figure 5.1

Hydrogen and the Laws of Physics

The Long and Winding Road: Hydrogen Production from Fossil Fuels

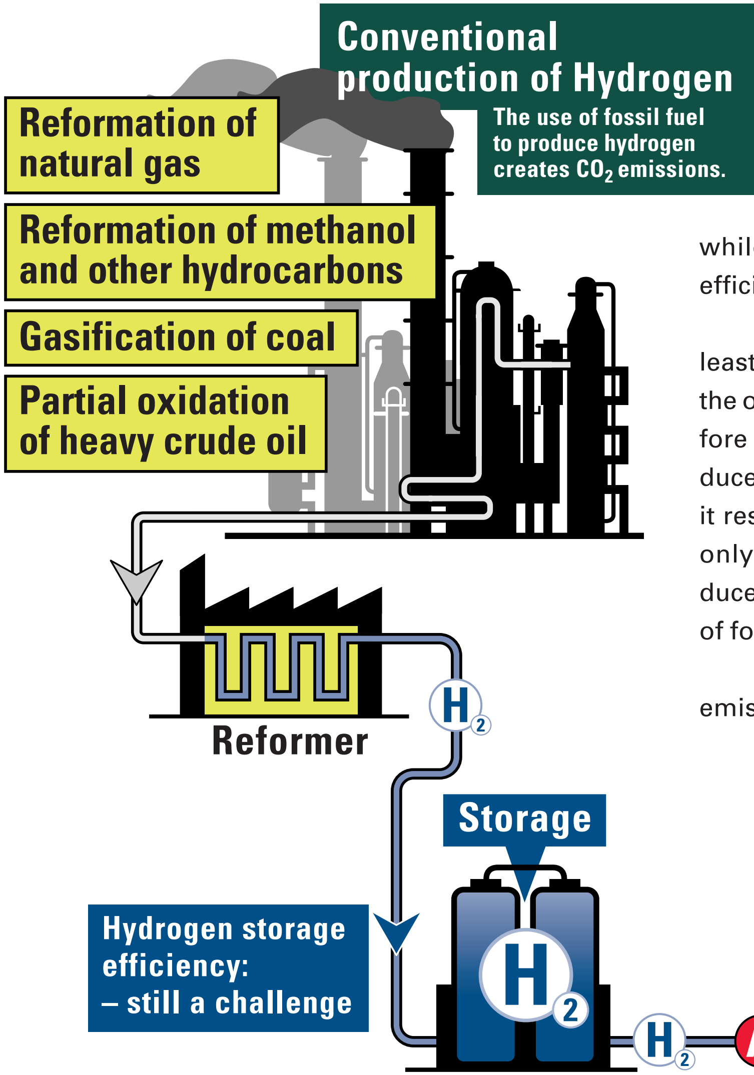
The world hydrogen production is not monitored, but estimated at 45 million tons (500 million cubic meters) per year, generating sales worth of about US$ 28 billion. It is used by many industries ranging from fertilizer to metal production. Hydrogen's largest use, however, is in the refinement of crude oil into gasoline that fuels our present system of personal transportation. Since hydrogen does not occur freely in significant quantities in nature, it must be extracted from the compounds it has reacted with. Electrolysis (chapter 5.1 Hydrogen and the Laws of Physics) is just one possibility to accomplish this separation. Currently the main method of hydrogen production, however, is the steam reforming of fossil fuels such as natural gas, oil, or coal (Figure 5.2). It does not need the large amounts of electricity that are needed for electrolysis, but does require large water and heat inputs.

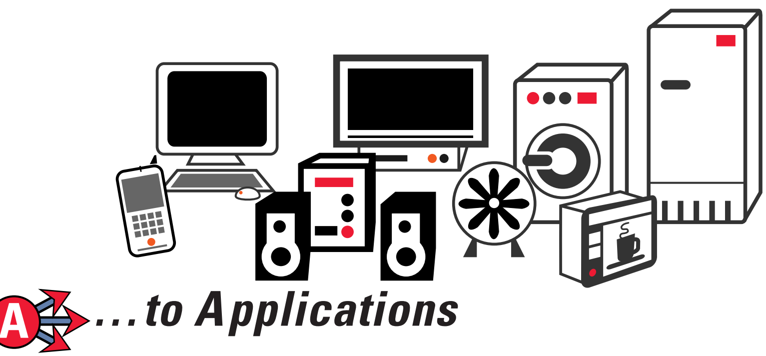
Reforming is a chemical process by which hydrogen-containing fossil fuels are reacted in the presence of steam and/or oxygen to form a hydrogen-rich gas stream and carbon oxides. When applied to solid fuels like coal, the reforming process is called gasification. The resulting hydrogen-rich gas mixture (the reformate) needs at least two further purification processes to remove compounds like nitrogen, carbon dioxide, carbon monoxide and other components of the source fuel. The feasibility of using the purified reformate in fuel cells, however, is still under question. The small amounts of impurities that are always present and, in fact, any fuel other than 100 percent pure hydrogen obstruct the power generation reaction within a fuel cell.

The overall reformer efficiencies mainly depend on the fuel and temperature used. In the end, high temperature reformers can achieve 65 percent efficiency while low temperature methanol reformers achieve efficiencies between 70 and 75 percent.

Steam reforming of fossil fuels is currently the least expensive method for producing hydrogen, and the only one which can be used at large scale, and therefore accounts for about 96 percent of the hydrogen produced worldwide. The downside of the process is that it results in huge amounts of GHG emissions and not only consumes non-renewable fuels, but also introduces additional losses into the conversion processes of fossil fuels into energy.

So are there alternative methods to avoid GHG emissions?





Data Source: own investigation

Figure 5.2

Hydrogen Production from Fossil Fuels

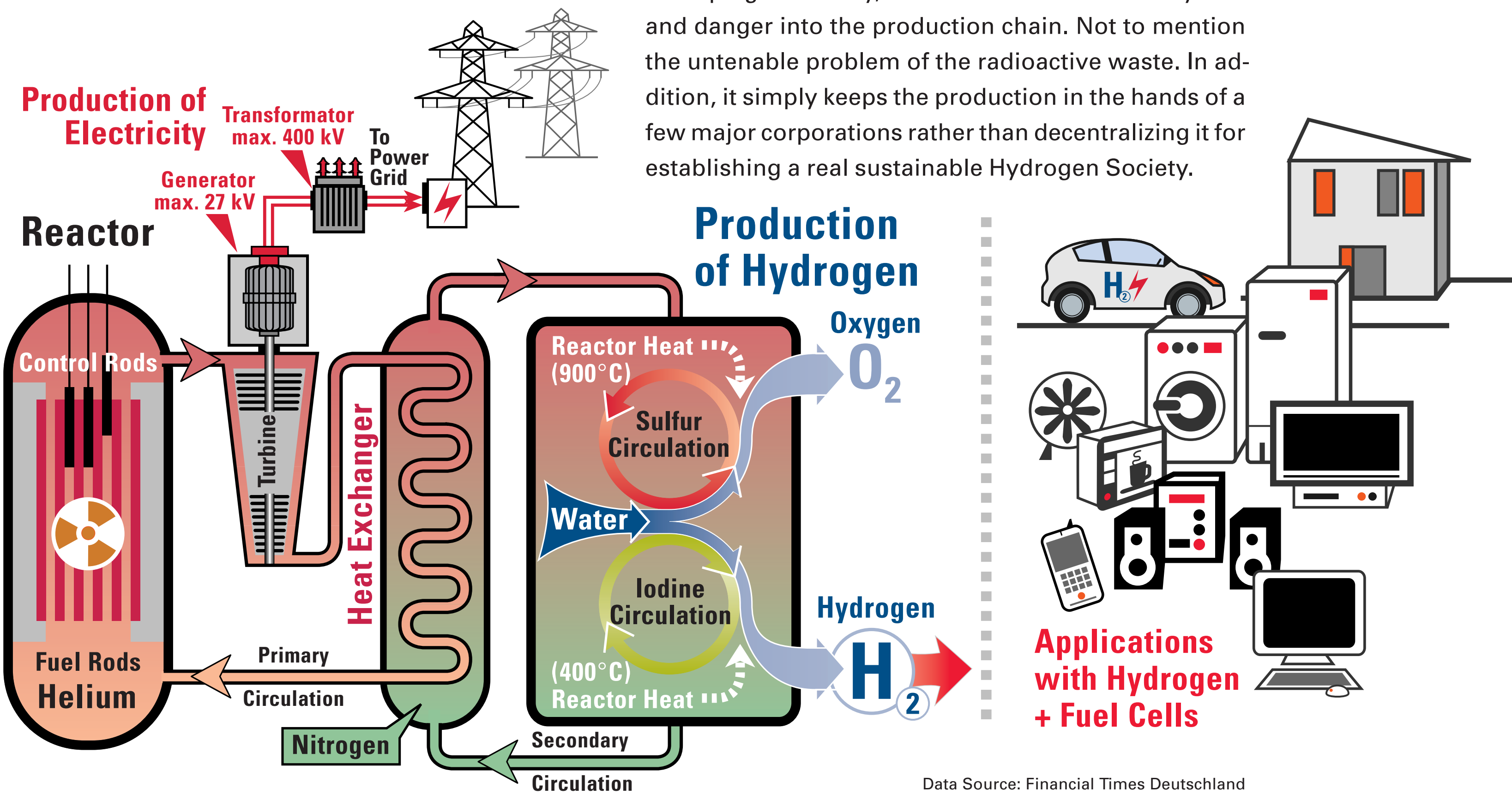
Under Research:
Hydrogen Production from Nuclear Energy

As shown in the previous chapter, making hydrogen from fossil fuels is currently the most common method of production, and is likely to remain dominant in the near term. All of the described fossil processes, however, produce significant quantities of GHG emissions, and thus would not be the energy source of choice to provide clean and environmentally friendly hydrogen. Using the nuclear option for hydrogen generation could avoid the release of GHG's, but I challenge you to label this hydrogen as clean or even green.

Nuclear power plants use nuclear fission reactions to create huge amounts of base-load electricity by using a small amount of the dangerous fuel uranium (see chapter 2.3 Onward, Backward: Electricity from Nuclear Energy). Once you have the electricity, and do not have an issue with its origin, you can easily hook up one or more electrolyzer(s) of required size(s) and let them separate the hydrogen from water.

A more futuristic approach is the production of hydrogen from nuclear-thermal energy (Figure 5.3). Substitution of thermal energy for electrical energy gives a somewhat higher overall efficiency because it simply converts more of the initial heat energy into chemical energy to make hydrogen. This process is under research since the 1970's, however, it has only been demonstrated in laboratories to date, not at commercial scales. The interesting aspect of the process is that it is not inextricably bound to nuclear reactors; all it requires is a high heat energy source which could also be provided by solar energy systems.

Based on my research, there is currently no utility or company using nuclear energy explicitly to make hydrogen anywhere on the globe. And we are better off in keeping it that way, as it would add unnecessary cost and danger into the production chain. Not to mention the untenable problem of the radioactive waste. In addition, it simply keeps the production in the hands of a few major corporations rather than decentralizing it for establishing a real sustainable Hydrogen Society.



Data Source: Financial Times Deutschland

Figure 5.3

Projected Hydrogen Production from Nuclear Energy (Generation IV)

Applied Thinking:

Hydrogen Production from Renewable Energies

Lake Starnberg (German: Starnberger See) in southern Bavaria is Germany's fourth largest lake, located adjacent to our office, and a good example of sustainability: With no natural headwater of note, the lake needs 21 years to regenerate completely on its own.

Although the goal that a sensitive humanity would like to achieve – decarbonizing the power sector while satisfying growing demand for electricity – is pretty clear, the right strategy to produce hydrogen is not. The world already produces large quantities of hydrogen for industrial proposes, but nearly all production today is based on fossil fuels. If the intention is to seriously pursue the goal of using clean hydrogen on a scale relevant for a Hydrogen Society, a real „Go to where the market is" approach needs to be deployed in a much faster rate than has been seen until now (see chapter 7).

Already in the 1970's, the first hydrogen romantics began thinking about desired energy sources for hydrogen production which should, above all else, be sustainable. As early as in 1974, namely at the international The Hydrogen Economy Miami Energy (THEME) conference, more than one third of the 71 presentations covered the production of hydrogen from renewable energies. Already then William Heronemus of the University of Massachusetts recognized that "Only Solar Energy Processes will bring us to the Hydrogen Economy", or take N.T. Veziroğlu from Miami University, co-founder of IAHE and writer of the preface of this book, who spoke about "The Dynamics of a universal Hydrogen Fuel System". Name your favorite renewable energy, and one of them has been imagined as a way of generating hydrogen by the hydrogen romantics. Yet the modest progress that has been achieved so far is alarming. After more than three decades, our deployment of renewable hydrogen production technologies has not advanced considerably. Based on current knowledge, renewable hydrogen can be produced in two ways, one with and one without the use of electricity.

In order to protect the lake from wastewater, a bill was passed to construct a ring sewer with a central wastewater treatment plant. Also private boats with combustion engines are not allowed to cruise the lake. But to keep our environment stable in the long term, we will have to change much more than just some laws.

Hydrogen Production from Renewable Energies with Electricity

The idea is captivating: to use the energy of moving air, water, or even the energy of the sun to produce clean electricity which in turn produces hydrogen using electrolysis (Figure 5.4). This gets even better when excess, off-peak power is used. A major characteristic of our current electricity grid is that user demand drives provider supply very strongly. With more and more renewable power plants, mainly wind farms, being installed and operated, one wonders why hydrogen is not more often used to buffer production peaks and fill gaps in supply. The concept is simple: use wind power as a variable source that would produce hydrogen when electricity demand is low, and to then use the hydrogen in fuel cells to produce electricity if demand exceeds the wind turbine supply. The combination looks like a natural fit because electrolyzers require direct current which wind turbines produce before being converted to alternating current suitable for the electric grid.

Are there any commercial programs in this direction? Indeed there are some, and one is currently in the construction phase in Germany built by an independent energy company named Enertrag AG which generates electricity solely from renewable sources. This company is one of the world's largest wind power producers, operating over 400 wind turbines with an annual yield of 1.35 billion kWh of electricity – sufficient supply for the household needs of one million people.

Hydrogen – to go

The intention of Enertrag AG is to build a hybrid power plant, using 3 x 2,000 kW of wind generators and 1,000 kW of stored biogas as feedstock.

They are going to store 1,350 kg of hydrogen, which is using a 500 kW electrolyzer with 120 Nm3/h nominal load at 30 bar at 75 percent efficiency. Furthermore, they plan to make electricity in a 350 kW CHP plant with 155 kW_{th}, using 70 percent hydrogen (max) and 30 percent biogas. The heat is used by 80 houses in a nearby town. Any surplus hydrogen is intended to be used for transportation. The hydrogen could flow in pipelines to hydrogen vehicle filling stations in Berlin, 120 km (75 miles) away from the site. Earth was broken for the hybrid plant in April 2009 with the German Chancellor Angela Merkel wearing a hard hat and carrying a shovel together with other celebrities from politics and industry.

This is, at least in theory, a step in the right direction. It is not a laboratory test, it is calculated with real world figures and carried out by a powerful utility with experience in renewable energies. One could not expect better conditions. The plant is supposed to go on the grid in spring 2010. Please stay tuned, we are all looking forward to first results.

Source: www.enertrag.com

◁ Hydrogen storage tanks at a filling station in Berlin, Germany, installed here to keep the filling time short at a maximum fill pressure of 700 bar.
One of the objectives is to prove everyday suitability of hydrogen for transportation purposes by real-life operation of hydrogen stations integrated into conventional filling stations.

Enertrag AG is a European IPP (independent power producer) specializing in sustainable energy. Enertrag currently operates more than 400 wind turbines with an installed capacity of over 720 MW and annual generation of 1.35 billion kWh, covering demand by approximately 1 million people.

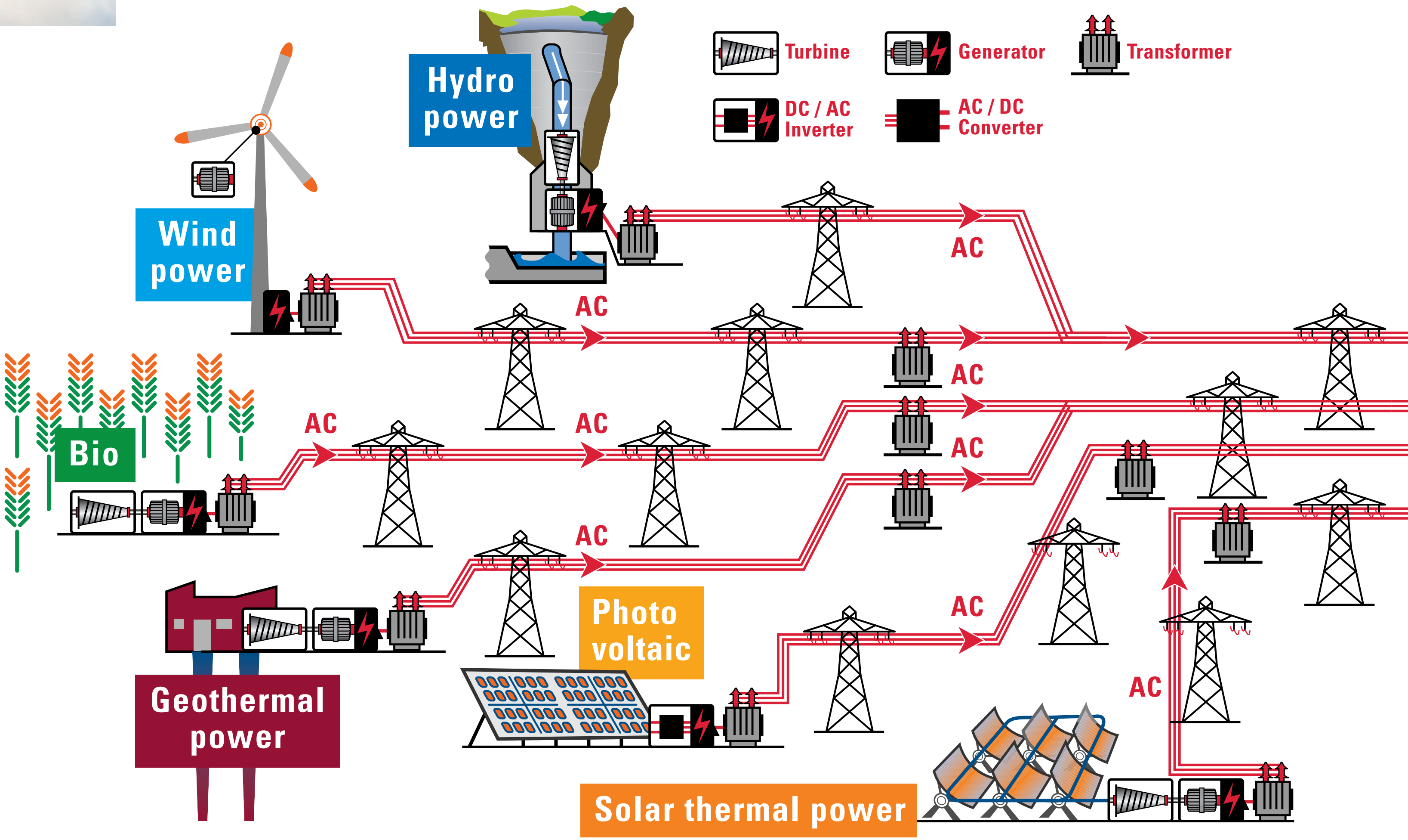
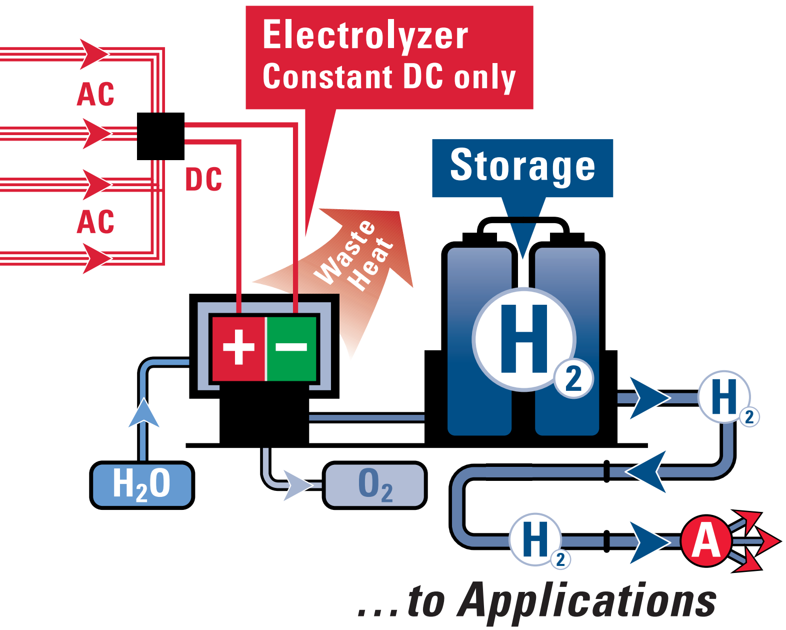


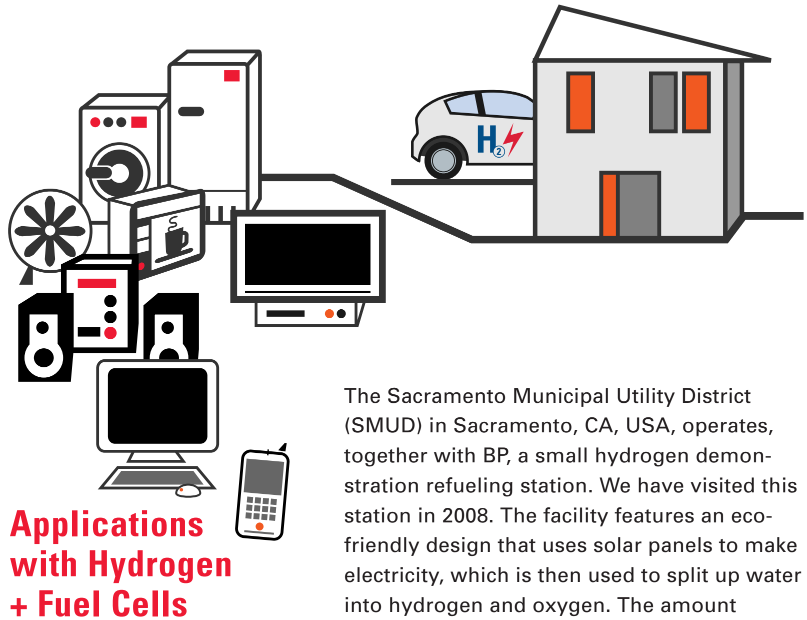
Figure 5.4

Production of Hydrogen with Electriciy from Renewables

At the Hamburg hydrogen filling station, electrolyzers supplied by NorskHydro Electrolysers (now Hydrogen Technologies AS, part of the Norwegian State Oil Company, Statoil) produce "green" hydrogen.
The electricity used in this process is generated by renewable hydro power, and is purchased from the Swedish state owned Vattenfall (Europe's fifth largest generator of electricity and the largest generator of heat).
The region around Hamburg in North Germany is relatively flat, and I wonder where the hydro power is actually coming from.



Data Source: own investigation



The Sacramento Municipal Utility District (SMUD) in Sacramento, CA, USA, operates, together with BP, a small hydrogen demonstration refueling station. We have visited this station in 2008. The facility features an eco-friendly design that uses solar panels to make electricity, which is then used to split up water into hydrogen and oxygen. The amount of hydrogen produced at the site is kept low. The station stores the equivalent of 50 gallons of gasoline, which is not much more than what a typical large commercial truck carries in its fuel tank. The station is not open to the public and is limited to use by SMUD and State of California fuel cell vehicles.

Hydrogen Production from Renewable Energies without Electricity

Although a renewable energy source in conjunction with electrolysis would eliminate the dependence on fossil fuels, it still requires the production of electricity in the first place. The overall efficiencies of these processes are thereby reduced. Alternative methods without the need for electrical power include:

Photoelectrochemical (PEC) hydrogen

PEC systems use sunlight directly to generate sufficient energy to split water into hydrogen and oxygen. The advantage over conventional electrolysis using photovoltaic is the elimination of an electrical current network and the associated current transmission losses.

Biological Photolytic Hydrogen

Another way to directly tap solar energy for hydrogen production is to take advantage of certain microalgae and photosynthetic bacteria that sometimes use photosynthesis to make hydrogen instead of sugar and oxygen. However, the algal enzymes that trigger hydrogen production are inhibited by oxygen, so bioengineering of enzymes or a whole new organism would be required to make this process even remotely practical.

Conversion of Biomass and Wastes

Hydrogen can be produced via pyrolysis (thermochemical conversion) or anaerobic digestion (fermentation) of biomass resources such as agricultural residues, wastes including plastics and waste grease; or biomass specifically grown for energy uses. Specific research areas include reforming of pyrolysis streams and development and testing of fluidizable catalysts.

Scientists are also working on “dark fermentation” reactions which do not require light energy at all. Here, a variety of bacteria ferment sugars and produce hydrogen using multi-enzyme systems. Sugars are relatively

Hydrogen from Biomass

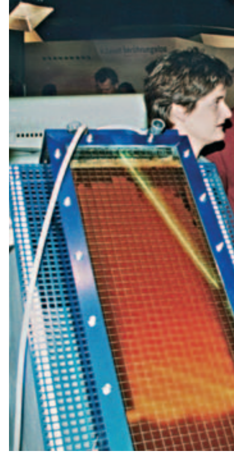
In research laboratories around the world, scientists are working on various options to produce hydrogen from biomass. One is the National Renewable Energy Laboratory (NREL), a national laboratory of the U.S. Department of Energy (DOE), based in Golden, Colorado, which I visited in August 2004. NREL possesses immense knowledge as well as practical insight when it comes to examining issues related to renewable energy sources and hydrogen production. At the time of my visit, NREL was developing, among other things, a pilot scale project focusing on hydrogen production by biomass gasification in a fluidized bed reactor.

They gave me a realistic picture about the complex numbers of biomass-to-hydrogen conversion processes and challenges from the standpoint of a research institution. Seen from my perspective, the technology has always been, and is still in an early stage of development with major potential for optimization. Each generation process still represents a huge investment, but is nonetheless realistic.

expensive substrates so engineering pretreatment technologies to convert lignocelluloses biomass into sugar-rich feedstock including hemicelluloses and cellulose that can be fermented directly to produce hydrogen, ethanol, and other high-value chemicals will be needed.

Solar Thermal Water Splitting
Water usually decomposes at temperatures of more than 2,500°C into hydrogen and oxygen. Researchers have demonstrated that highly concentrated sunlight can be used to generate these temperatures. However, catalysts based on metals or inorganic sulfur compounds can lower the heat needed to the more moderate range of 800 to 1,200°C. Such high-temperature, high-flux solar driven thermo-chemical processes offer a novel approach for the environmentally benign production of hydrogen, and thus shall be explored in more detail in chapter 5.5 Here Comes the Sun.

All the above mentioned methods are still in experimental phases and capable of supplying only small amounts of hydrogen. It seems that many technical, economical, and even mental hurdles need to be over-



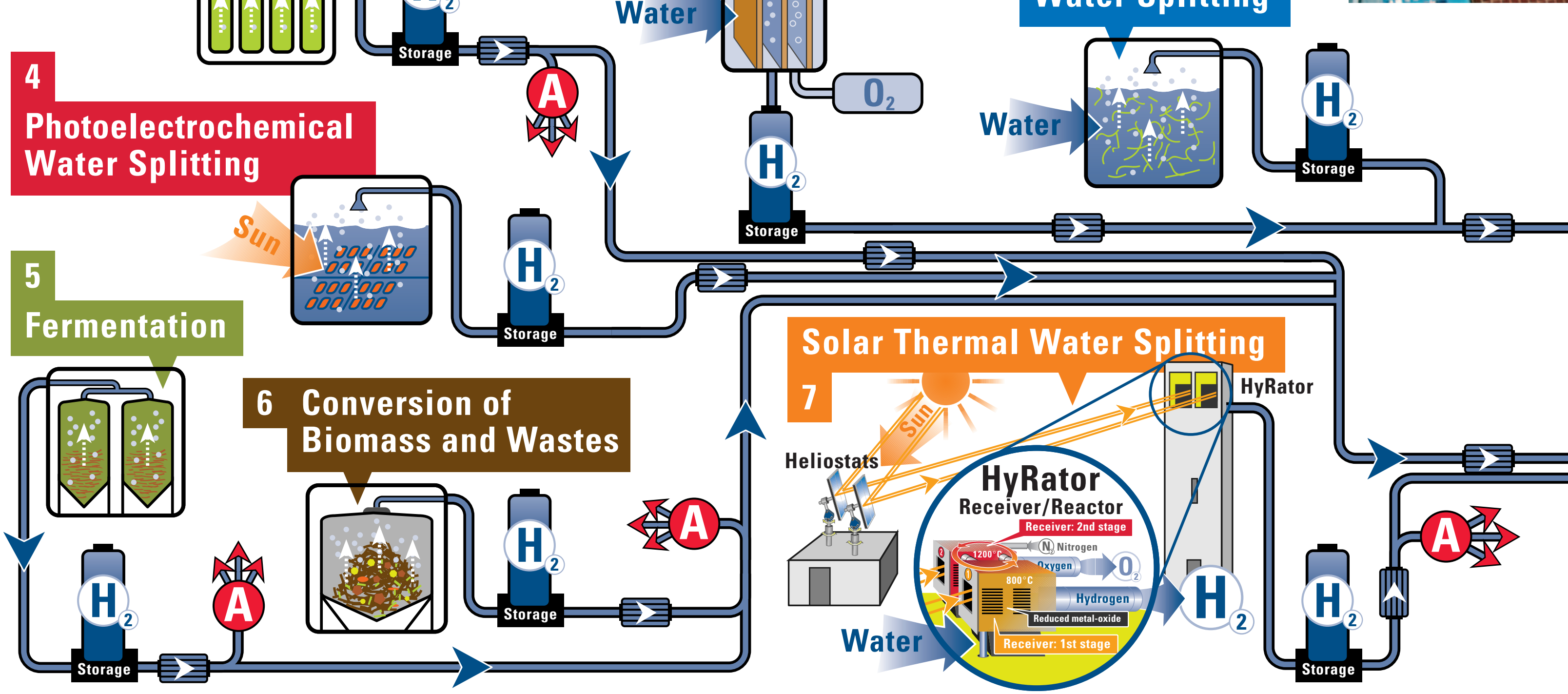


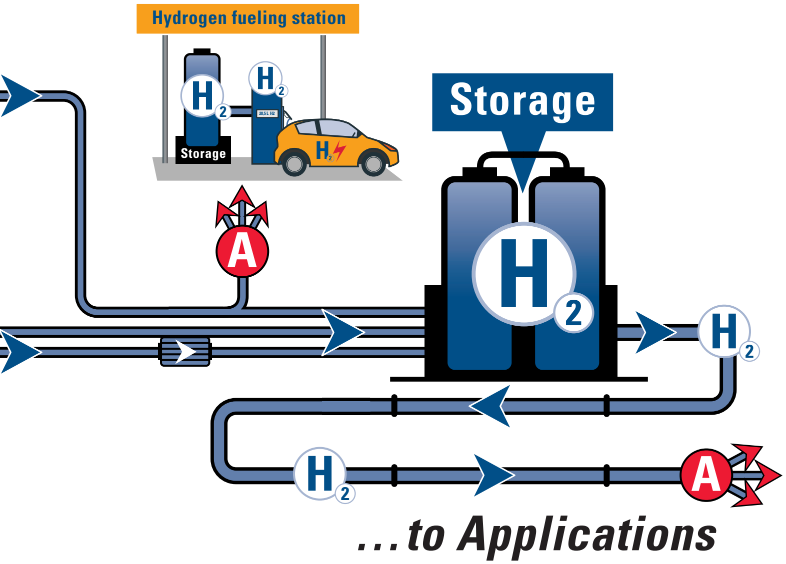
Figure 5.5

Production of Hydrogen *without* Electricity from Renewables

Living purple bacteria are considered the best means of photobiological hydrogen production. These bacteria absorb light within the visible range, and then transform it into molecular hydrogen. No oxygen is evolved in this process. This process was already shown „in situ" at the HANNOVER FAIR 1995 by the German researcher Dr. Sabine Tramm-Werner (left), Technical Microbiology, Aachen.

come before widespread commercial scale production of clean hydrogen is possible. But this would overstrain the activities of researchers who, no doubt, with skill and resourcefulness have pieced together an amazingly detailed picture of the most common element in our universe over several decades. Yet many of their concepts remain the same as those voiced by our earlier hydrogen pioneers in the 1970's. Their customers may be buyers and sellers from the industry, but the type of systems that could be commercialized cannot be seen, at least from my point of view.

To find our way forward, we first have to reshape the tools developed by scientists and utilities decades ago to new uses for which they were never intended. We need to use our imagination and continue working on creating a range of possibilities which can accommodate different renewable energy sources for hydrogen production in different locations of the world to replace the armada of fossil fuels. And the power of the sun may lead us in the right direction.



Data Source: own investigation

Multielectron reactions are fundamental to promoting energy conversion transformations such as the oxidation of water and the reduction of hydrohalic acid to hydrogen. Daniel G. Nocera, The Henry Dreyfus Professor of Energy and Professor of Chemistry at the Massachusetts Institute of Technology (MIT), is one of the leaders in this field.

Here Comes the Sun:
Direct Solar Hydrogen Production

As we covered earlier in this book, most of the "environmentally friendly hydrogen technology" is currently using hydrogen from fossil fuels, mainly produced by reforming of natural gas. This hydrogen is not at all CO_2 free, and certainly not renewable. Nevertheless, many representatives fromfrom media, politics, and administration are creating the impression that everything that is converted in a fuel cell into electricity, heat, and water is "100 percent clean, 100 percent steam".

With this in mind, it is surprising that hydrogen is often considered as being the "green" alternative for fossil fuels. This miraculously transfer takes place the second that hydrogen is pumped into a car or bus. In an instant, the hydrogen, which was originally made from fossil fuels, suddenly turns green. Some large car manufactures with competent legal departments are clever, and state: "Our H_2 cars are consuming hydrogen, a locally green and environmental friendly fuel" to avoid liabilities or further questions. This sentence is – at first glance – legally correct; however, in my opinion it is just cheating the concerned citizens. The pollution has only been shifted up-stream, from the tailpipe of the car to the chimney of the refinery or reformer where the hydrogen was produced.

The same magic occurs in stationary applications. When installing a stationary combined heat and power unit in a house it is important to ask where the fuel comes from. In most cases this will be natural gas reformed in-house for the fuel cell stacks and by nature emits CO_2 and other greenhouse gases during operation (see chapter 6.2 Residential Fuel Cells).

HYDROSOL Project Summary

High intensity solar radiation can be obtained from existing parabolic reflectors that track the sun via heliostats. The areas of southern Europe which possess high solar flux and potential for installation of the associated solar tower plants are largely coincident with economically depressed regions.

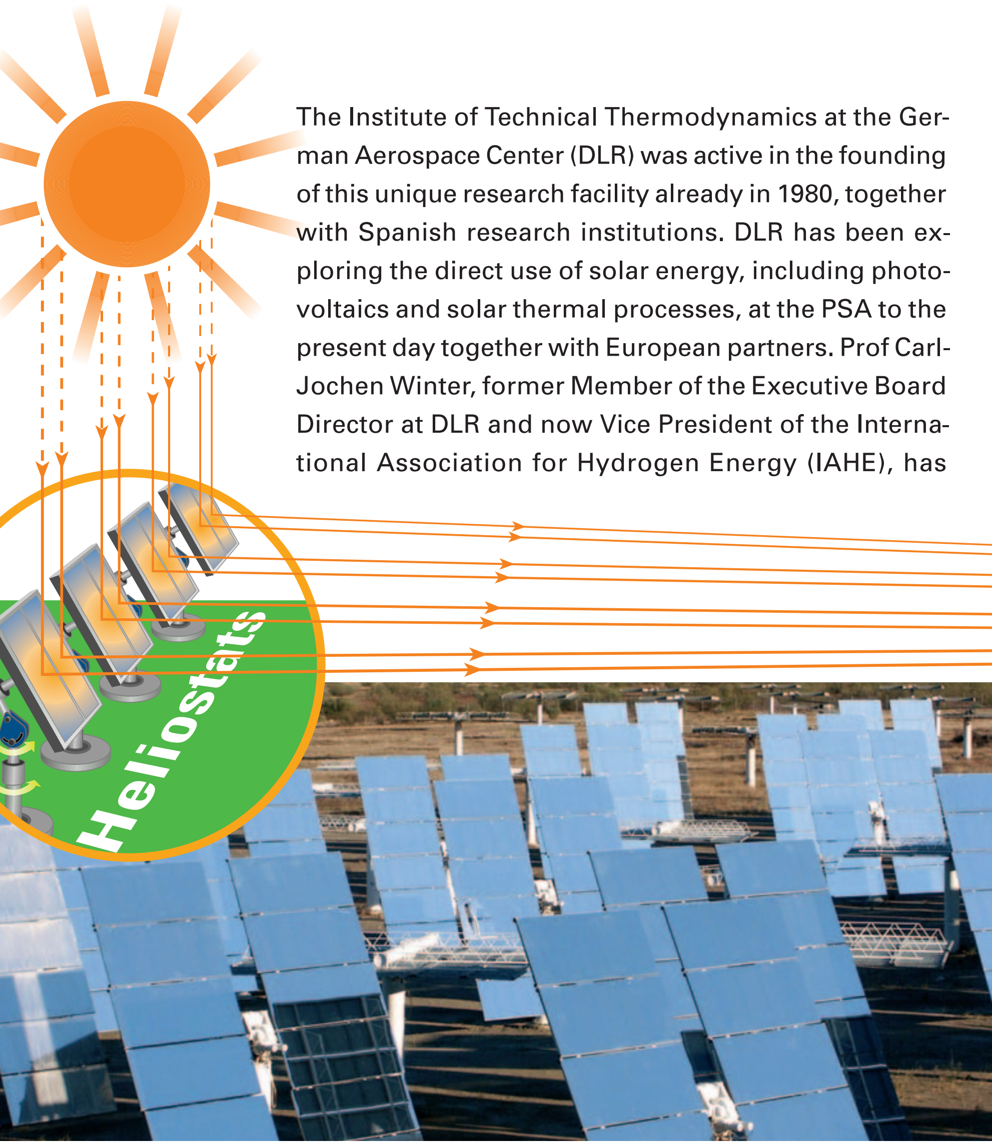
The HYDROSOL Project is an effort to employ a renewable energy source, the sun, to directly produce hydrogen, a "clean" fuel considered to be the energy carrier of the future given the advancement of fuel cell technology and hydrogen storage/handling systems. Scientific objectives and approach:

By far the most economically attractive reaction for the production of hydrogen is the decomposition of water (hydrolysis) and the direct production of pure hydrogen. However, because of unfavorable thermodynamics worthwhile yields can only be achieved at very high temperatures imposing therefore technological difficulties to any ideas trying to couple the sun as the source of driving energy for the reaction. Catalytic materials are therefore required in order to lower the reaction temperature.

HYDROSOL

To me, the origin of hydrogen is the crux of the matter, and we should not stop asking about it. Much of present literature reveals that many hydrogen enthusiasts do not make the distinction between energy carrier and energy source or enquire how the hydrogen is actually produced.

That said, we should actively and purposefully keep emphasis on new processes for making hydrogen, preferably in a new, sophisticated manufacturing step. I had the chance to see the HYDROSOL 2 project, one solution of the direct solar production of hydrogen (Figure 5.6), which was installed and tested in 2009 at the "Plataforma Solar de Almeria" (PSA) in Southern Spain.



The Institute of Technical Thermodynamics at the German Aerospace Center (DLR) was active in the founding of this unique research facility already in 1980, together with Spanish research institutions. DLR has been exploring the direct use of solar energy, including photovoltaics and solar thermal processes, at the PSA to the present day together with European partners. Prof Carl-Jochen Winter, former Member of the Executive Board Director at DLR and now Vice President of the International Association for Hydrogen Energy (IAHE), has

Applied Technologies:

The hydrolysis reaction is carried out via a two step process. In the first step the activated catalyst dissociates water and produces hydrogen while in the second step the used catalyst is regenerated releasing oxygen. The concept has been proven experimentally, however the catalyst regeneration temperatures are still high (i.e. >1600°C).

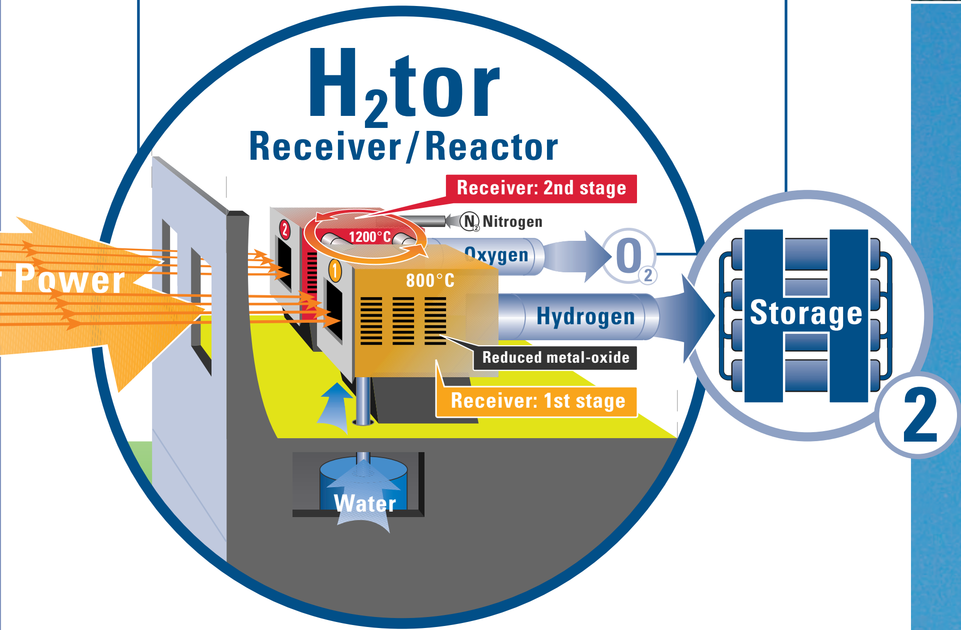
The aim is to combine a support structure capable of achieving high temperatures when heated by concentrated solar radiation with a catalyst system suitable for performing water dissociation and at the same time capable of regeneration at these temperatures, so that complete operation of the whole process (water splitting and catalyst regeneration) can be achieved by a single solar energy converter. The purpose of the HYDROSOL project is thus two-fold:

1) The development of novel catalytic materials for the water dissociation reaction at moderate temperatures (800 to 1,200° C) and of the associated technology for applying a coating to a support structure, and

2) The integration of the developed material technologies into a solar catalytic reactor suitable for use in solar energy concentration systems, opening the road towards a complete hydrogen fuel production unit based solely on solar energy.

HYDROSOL

The Direct Solar Hydrogen Production process had its first successful tests in November 2008 at the Spanish Plataforma Solar de Almeria, after initial pilot tests at the DLR in Germany. The two solar receiver-reactors are mounted 28 meters high on the so-called SSPS Tower (Small Solar Power System). The units are installed in a modular fashion, currently designed for 100 kW. The structure is relatively unspectacular; the two reactors have the size of a normal household refrigerator. The currently installed solar heliostats (mirrors) at the PSA research center, which automatically track the sun, have a thermal capacity of max. 2.7 MW. The location in Tabernas/Spain, with over 3,000 hours of sunshine per year and a direct solar radiation of 1,900 kW/h per square meter, provide Europe's best solar power.



Data Source: own investigation

Figure 5.6

Direct Solar Hydrogen Production

Green Hydrogen
produced from clean, renewable energy sources rather than from fossil fuels

Golden Hydrogen
produced directly from the sun to support decentralized energy production and usage

signed the cornerstone for the establishment, as the Small Solar Power System (SSPS) Operating Agent, together with the Spanish Ministro de Industria y Energia and the IEA Executive Director, on January 17, 1980, in a pioneering step which has been maintained until the present day by many active European scientists, researchers and technicians. I was informed in February 2010 by the HDROSOL coordinator from Greece, that the activities in this area are continuing in a follow-up project called HYDROSOL 3D that focuses on the design of a 1 MW plant. Good news, indeed!

There is no doubt that in the long term hydrogen must be produced exclusively from raw materials which are free of carbon. These raw materials can be water and sunlight. The direct solar hydrogen production used in thermal processes does not need any coal, natural gas or oil. Additionally, it also saves the step to convert energy from heat into electricity and the high flaring and transmission losses within the existing electricity system. In the end, this hydrogen can even be called "golden hydrogen".

A worldwide introduction of this process, with the hydrogen as a fuel for distributed generation of electricity, heat and water, as well as provision of transport service will provide a truly renewable and emission-free future. However, this step requires a rethinking within today's energy system. There must be a transition from the current "electricity, gas and oil industry" with all its pipelines, refineries and high/low-voltage networks to a decentralized green/golden Hydrogen Society. As long as hydrogen only becomes clean with a trick at the instant it is fueled to a car, laptop or a stationary unit, we will not get very far. The real green/golden production process of hydrogen must be a comprehensive one: clean in all stages of production.

From my perspective, the resistance to green (golden) hydrogen production at this time is more mental than technological. While this resistance may be large, it can be overcome. With this in mind, let us start to navigate the boundary between reality and fiction.

Expected impacts:
The integration of technology for concentrating solar radiation with reactors able to split water molecules forms a system of immense value and impact on energy supply and economics worldwide. The project is focused on a key technology for using solar heat to drive chemical processes (hydrogen production) aiming at reaction yields which, when obtained over the temperature range described above, are a significant improvement over the current state of the art, and represent a significant opportunity for commercializing the technology.

The project will have a significant impact both in contributing to the achievement of ecological objectives (emission reduction, natural source preservation) as well as in job creation and economical growth, especially to underdeveloped EU areas since these largely coincide with regions/latitudes of high levels of direct solar flux.

The HYDROSOL consortium consists of two industrial R & D partners and three research partners:

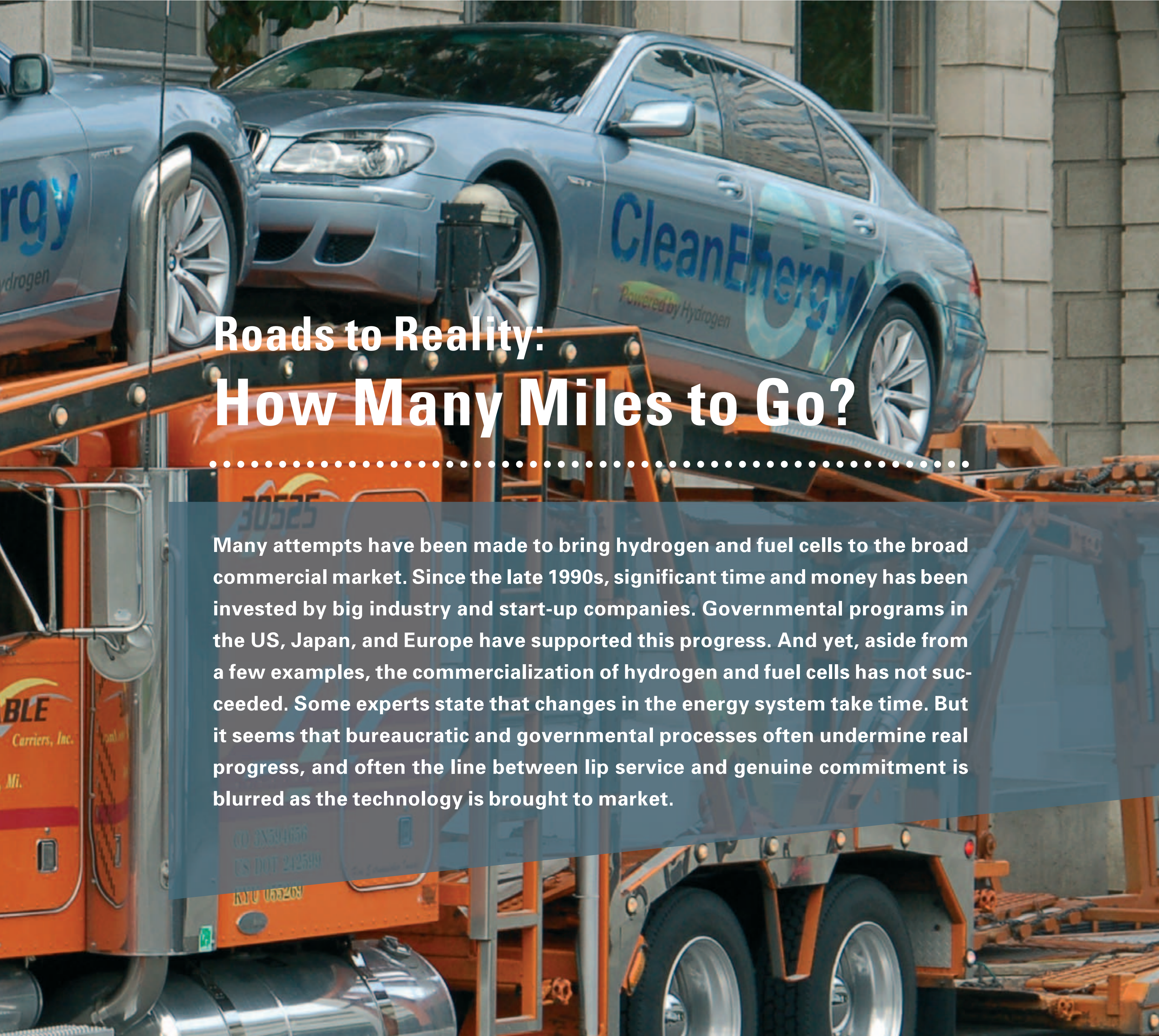
- *Johnson Matthey Fuel Cells Plc., UK*
- *Stobbe Tech Ceramics A/S, Denmark*
- *Aerosol & Particle Laboratory CERTH-CPERI, Greece*
- *Centro de Investigaciones Energeticas, MedioAmbientales Y Tecnologicas – CIEMAT, Spain*
- *Institute of Technical Thermodynamics at the German Aerospace Center (DLR), Germany*

Source: http://www.hydrosol-project.org

HYDROSOL

Tests of Advanced Sodium Receivers (ASR) were carried out at PSA to explore the potential of sodium as a heat transfer medium. Due to the explosiveness of sodium, today other media are used as heat carrier. However, the experiences from the design, manufacturing, and assembling of the ASR led to the successful operation of the HYDROSOL project.

6



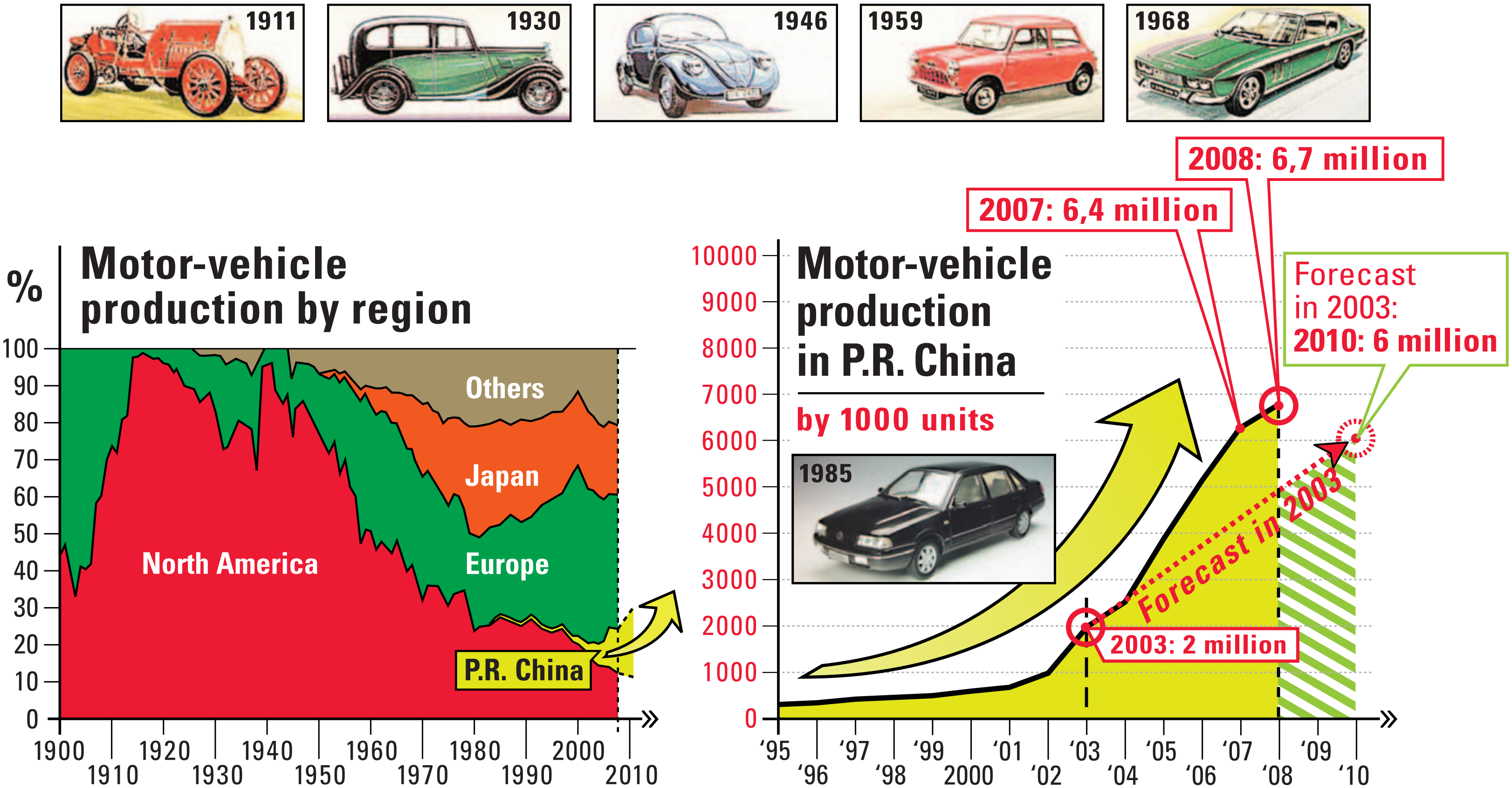
Roads to Reality:
How Many Miles to Go?

Many attempts have been made to bring hydrogen and fuel cells to the broad commercial market. Since the late 1990s, significant time and money has been invested by big industry and start-up companies. Governmental programs in the US, Japan, and Europe have supported this progress. And yet, aside from a few examples, the commercialization of hydrogen and fuel cells has not succeeded. Some experts state that changes in the energy system take time. But it seems that bureaucratic and governmental processes often undermine real progress, and often the line between lip service and genuine commitment is blurred as the technology is brought to market.

Ticket to Ride:
Can Cars Carry that Weight?

Exciting times these are! The automotive industry was once a symbol of technology leadership and an undisputed source of profits (creating well-paid jobs). Now it is “reaching a state of emergency”. Former market leading auto makers have either been fully or partially bought by the government and in some cases management has even been transferred to the state. The small Italian company Fiat swallowed the big American manufacturer Chrysler. The German government had put up a Euro 1.5 billion bridge loan to keep General Motor’s German daughter Opel afloat, to hand it over to automotive parts maker Magna International and Russian Sberbank. The deal eventually was cancelled and the taxpayers’ money thereby evaporated! Japanese Toyota struggles with recalls of more than 8 million cars worldwide to address problems with removable floor mats and sticking accelerator pedals. The issue has even prompted a congressional inquiry and apologies from Akio Toyoda, chief executive, in the USA and China.

At the same time, new competition begins to emerge (Figure 6.1): Asian car companies in India and China now exploit the potential of existing resources more effectively than their Western counterparts. Market proximity, low labor costs, and progressive innovation strategies are just some of their advantages. Nobody can blame them for wanting in on the action! For example, China started its domestic car production in 1985 and since then its production skyrocketed to over 6.7 million units in 2008. Back in 2003 the chinese government forecasted a new vehicle production increase to 6 million cars not before 2010, a quantity which has already been reached in the year 2007. That means, we should not underestimate predictions from China.



Data Source: Prognose-Institut B&D Forecast; www.oica.net

Figure 6.1

World Passenger Car Production 1900 – 2008

Electric vehicles are another global fad which is, (in most cases) heavily reliant on state subsidies. But the big car manufactures seem to be quite reluctant in introducing them into the commercial market. There are exceptions, though:[1]

A presently small American car company named Tesla Motors, Inc., is developing and selling a "… high performance, super efficient electric car …" named Roadster. It features a range of 244 miles on a single charge and a supercar level 3.7 second 0 – 60 mph acceleration time. The price for such a device: Around US$ 100,000 without extras, plus tax, where applicable. Showrooms in London, Munich and Monaco are open, waiting for wealthy customers to place their orders.

But Tesla is also learning to drive more modestly with a planned all-electric Model S for a base price of US$ 49,900:[2] It is designed to offer a variety of range options depending on the battery pack used, from 160 to 300 miles on a single charge. Volume production of the Model S will begin in 2012 with a target production capacity of 20,000 vehicles per year by the end of 2013. For the construction of two manufacturing facilities, Tesla is going to receive a US$ 465 million loan from the U.S. Department of Energy (DOE) to support the mass production of its Model S.

The producers, distributors, and sellers of electricity, however, are globally delighted about this new and profitable future line of business. This new business comes to them with no conceptual effort from their side whatsoever. Together with some car manufacturers and in most cases highly subsidized by governmental support, they now open "hundreds of …" trial car battery charging stations like the ones in London, UK or Berlin, Germany. Battery manufacturers, (many based in Asia, and already strong on its own with their existing marketing, manufacturing, logistic and standards system), are working on solutions to reduce size and weight of the batteries for the powertrains in cars, and at the same time to improve power management and the cell energy density.

Hydrogen vehicles, either with H_2-combustion engines (BMW, Ford) or fuel cell systems and electric motor(s) in the powertrain, have existed since the early seventies. In the meanwhile almost every major car manufacturer has experimented with them. The waves of activities are intermittent, mostly depending on the

1) http://www.teslamotors.com/

2) http://apps1.eere.energy.gov/news/enn.cfm?printfull

The BMW Hydrogen 7 has a bi-fuel (liquid hydrogen and gasoline) 6.0 liter V12 combustion engine with 191 kW: „… the world's first production-ready hydrogen vehicle". Here seen at the 2007 China International Hydrogen & Fuel Cell Investment & Trade Expo (HFCE) in Shanghai, PR China.

Hydrogen cars, converting H_2 into electricity with fuel cells, observed at international exhibitions: General Motors (GM) predecessor concept car "Autonomy" (left), 1:1 cross section model of the former Daimler FCell (middle left), former versions of the Honda FCX (upper right) and the FCell as an A Class model.

All these vehicles, which are in their prototype versions, have aroused high expectations worldwide. But not one of them reached the showrooms of car dealers – at least that was the case in Spring 2010.

whim of the CEO's at the helm of the automakers and the availability of government funds. Both these factors change; they cannot be a sound foundation for future long-term commitments.

All of the hydrogen cars that exist today were hand built in rather limited numbers. I think I have driven them all at various locations worldwide. It was my pleasure to talk to the people, who had to get them on the road and kept them running. Intelligent and smart people who will desperately be needed in the future! It was always funny, though, to see the heavy trucks with the hydrogen cars loaded on them, waiting "around the block", to carry them on the long distant journey back to their base stations after the official ride and drive was done and the cameras were switched off.

Thanks to immense public relations efforts, some manufactures act perfectly to create an impression that many more hydrogen vehicles exist than actually do. Some were given to celebrities for a certain period of time with much media attention – and later taken away again, of course without cameras rolling. The mass-market production of hydrogen powered cars, which was announced in the 90's as being ready in 2010, has been often postponed. According to recent "official" sources from the car industry, mass market production is now to come "... in 2015 or in 2020". Or maybe even later? Or maybe even not at all? These questions still remain unanswered.

The trend in the world wide car industry for the last eleven decades was quite clear: Squeezing more and more functionality into much bigger and heavier cars. Every new model grew by a few inches and by more than a few pounds. New classes like 4 wheeled SUV's were invented, today being mostly driven in urban areas consuming large amounts of fuel quite senselessly.

Heavy black cars,
burning huge amounts of petrol
are hard to sell in 2009,
even in San Diego, CA, USA

Shanghai:
Street view in 2004;
times are changing …

That is how the automotive industry has tried, and still tries, to keep its customers satisfied. But customers in the USA differ from customers in Germany, Japan, China, and India. Unfortunately, besides of some good examples from Asia, like the Nano – The People's Car from Tata Motors[3] in India, I can not see many activities being directed toward finding transportation solutions that suit the needs of the next generation.

It looks like that today's car manufacturers do not even know what the future market really needs. It looks like the only sure goal for the existing system is to stretch the remaining resources, especially in form of crude oil to turn it in combustion engines, as long as possible. But all our gauges are edging toward empty.

Although long recognized and taught at some progressive universities and engineering schools, only limited concept cars exhibit the capabilities of lightweight, low drag, or modern material design. Product life cycle management often appears to be a foreign concept. There are no noticeable activities towards a new, more holistic approach regarding how to make the next generation of our more than 800 million cars more sustainable. What we need are meaningful activities towards universally networked and personalized new concepts for our entire transportation system on rail, road and in the air. But in my opinion, these new trends will not come from existing global automotive players. They may come from smaller companies, unknown today. Let them do their best!

To achieve a shift in attitude towards vehicle design, manufacturing and usage, though, environmentally progressive visionaries, scientists, economists, designers, engineers and even laymen must not only take over the leadership, but also become the master carbuilders of the twenty-first century. At this point, the informed and concerned citizen has more power than she or he knows. Her or his decision to purchase the "right" goods and services can be cheaper and more effective than any regulation under public law, which brings us to the next appliance for hydrogen and fuel cells: the micro-CHP system.

3) http://tatanano.inservices.tatamotors.com/tatamotors/index.php

Residential Fuel Cells:
Chemical Process to Produce Hydrogen

The idea sounds convincing: replace your standard gas boiler with a micro-CHP (combined heat and power) system based on fuel cell technology and be your own producer of clean heat, hot water and electricity. We do not mean the rather old fashioned CHP units, which are most often running on diesel combustion engines and therefore carry the burden of a heavy environmental footprint. We are talking about small units equipped with modern technology located in the basement of your house or hanging from the wall, providing almost all the electric and thermal energy needed for domestic use. In many cases, it is even possible to share surplus electricity with your neighbors via the low voltage network.

So, how does it work?

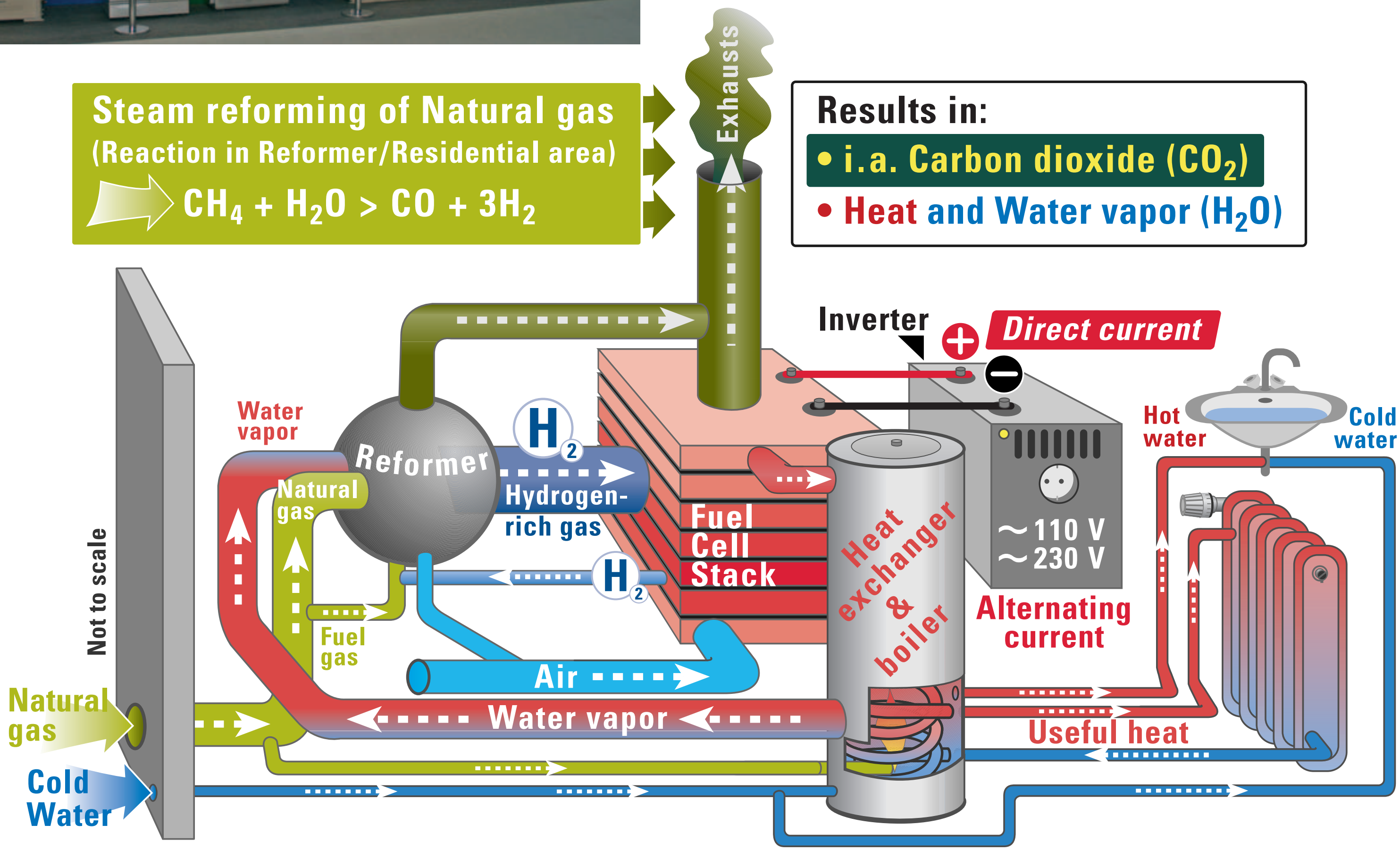
The majority of micro-CHP systems based on fuel cell technology today use natural gas as a primary energy which is converted into hydrogen by an integrated reformer (Figure 6.2). In an exothermic reaction, the fuel cell then uses the hydrogen as input fuel to produce (together with oxygen) heat and DC electricity. The micro-CHP unit is fitted with an integrated heat exchanger to recover the heat from the fuel cell stack in order to use it for space heating and hot water. A separate water tank can be connected to the unit as well, to store the heat and thus increase the total system efficiency.

At the moment, there are two leading technologies:

1. Units that use PEMFC (Proton Exchange Membrane Fuel Cell) technology and operate at temperatures from 80°C to 100°C and therefore have rapid start up times.

2. Units that use SOFC (Solid Oxide Fuel Cell) technology. They operate at somewhat higher temperatures and thus offer a better net electrical efficiency and relatively less heat.

The Japanese NEDO (New Energy and Industrial Technology Development Organization) is supporting research & development on hydrogen and fuel cells. Here exhibiting at the HANNOVER FAIR in Germany.



Data Source: ASUE, EnergieAgentur.NRW and own investigation

Figure 6.2

Residential Fuel Cells – Chemical Process to Produce Hydrogen

Almost all micro-CHP systems for domestic use on trial today generate not more than 1kW of electricity per hour while providing up to 1 kW (SOFC) and 1.7 kW (PEM) of thermal output for space heating and hot water. If the heat demand is higher, a supplementary burner can be fired up to fill the gap. If the electricity demand is higher, it can be obtained from the grid. Despite these necessary occasional inefficiencies, the overall system efficiency is approximately 80 percent.

What are the benefits? First and foremost, electricity (and heat) is generated locally, which is much more efficient than transmitting it over long distances on the grid. Unused electricity in turn is exported over the low voltage network to the nearest available load, while unused heat is stored in a water tank.

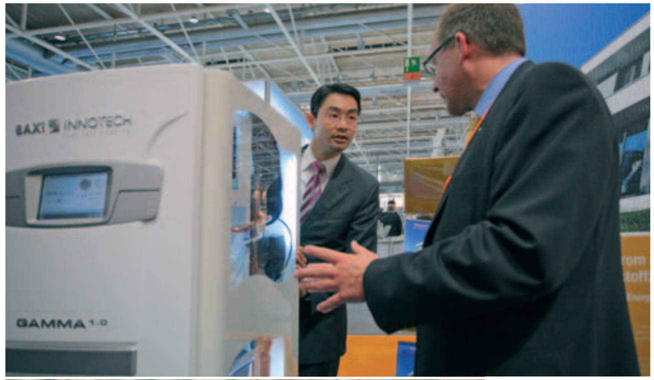
But can we really talk about “clean in-house residential hydrogen generation” as it is often stated in brochures and advertisements? Unfortunately, not! The hydrogen, as obtained from the natural gas grid, is neither clean nor renewable. At the most, it is “low carbon”, because less carbon dioxide is produced when taking natural gas directly from the gas network than would be if it were to be generated from other fossil fuels and transported in compressed or in liquid form from A to B.

Before natural gas can be used as a fuel, however, it must undergo extensive processing to remove almost all its components other than methane. The by-products of that processing include ethane, propane, butanes, higher molecular weight hydrocarbons, elemental sulfur, carbon dioxide, water vapor and sometimes helium and nitrogen. This is all normally extracted in refineries before it is inserted into the natural gas pipelines (and therefore before it eventually indirectely puffs through your chimney when you operate your micro-CHP unit).

The unfortunate fact is that such a 1 kW_{el} / 1kW_{th} micro-CHP unit in your house probably won’t satisfy all of your heat and electricity demands. Once again, you are fully dependent on both your local gas supplier and your electricity utility. They supply additional heat from an extra boiler, and additional power from grid electricity to the house. The local providers in turn have to rely on continuous supply from their own suppliers, who might be located in Russia or Ukraine for gas or in France for nuclear power.

In light of these facts, hydrogen powered micro-CHP units are just one of many solutions in the right direction, even though their environmental benefit depends on the fuel used and their overall electricity and thermal output. What happens when we equip every home with such a unit and link them together will be explored in next chapter.

Hydrogen powered micro-CHP units like this one from Hexis Ltd., Switzerland, are compact, with low emissions and virtually silent. This is a system with high efficiency that generates electrical power and heat from natural gas in a decentralized form in the basement of a single-family home.



Dr. Philipp Rösler (left), former Minister for Economics, Labour and Transport, Deputy Prime Minister of the state of Lower Saxony, Germany and Dipl.-Ing. Guido Gummert, Managing Director, BAXI INNOTECH GmbH, Hamburg, Germany, are having a close look at the GAMMA 1.0 – providing a new standard for power and heat in the home.

Virtual Fuel Cell Power Plants

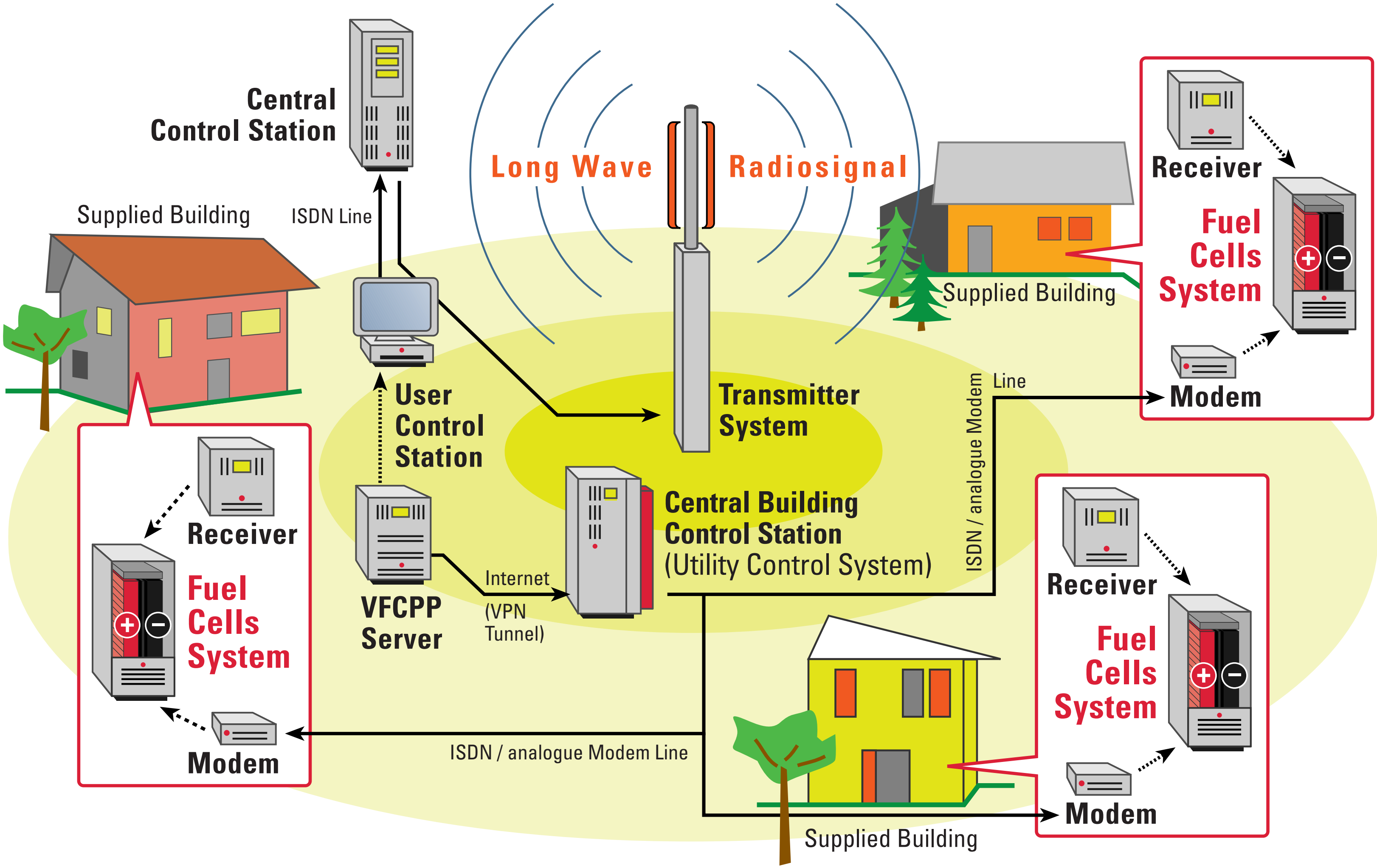
When a new product such as the micro-CHP is designed, it has to be assessed using trials with real users that represent a variety of geographic market areas. Europe is a key area because urbanization is high, different cultures reflecting different needs are in close proximity, and electricity supply is mature. There are almost 196 million households in the European Union, and each consumes energy for all of life's necessities such as heating, washing, lightning, cooking etc. Heating and hot water supply is responsible for a substantial proportion of the average home's energy consumption.

Given these conditions, carrying out usability evaluations of combined-heat-and-power systems – here we only concentrate on the micro-CHPs based on fuel cell technology – can be quite instructive. Moreover, linked together as a virtual fuel cell power plant, these systems might set a trend towards a decentralized power supply, generating heat and electricity at the point of use without excessive losses.

A virtual fuel cell power plant consist of a group of interconnected decentralized residential micro-CHPs which are installed in multi-family-houses, small enterprises, public facilities etc., for individual heating, cooling and electricity production (Figure 6.3). Centrally controlled and grid-connected, these elements of the virtual power plant also contribute to meeting peaking energy demand in the public electricity grid. An energy management system permits the monitoring, control, and evaluation of power transfer from any given node using nothing more than a standard PC.

In Europe, the most noteworthy activity in this area to date has been the EU FP5 Project "The Virtual Fuel Cell Power Plant" (EUVPP) which was carried out

3) http://www.initiative-brennstoffzelle.de



Data Source: European Virtual Fuel Cell Power Plant

Figure 6.3

Virtual Fuel Cell Power Plant

from November 2001 to March 2005. The total budget for installing 31 PEM micro-CHP systems in seven European countries was about Euros 8.6 million, 70 percent of which was paid by the 11 European project partners (Vaillant, Plug Power Holland, DLR, Cogen Europe, etc.) and 30 percent of which was contributed by the European Union.

All installed micro-CHP systems, each of which with an electrical output of 4.6 kW and a thermal output of 9 kW, combined to form a virtual power plant to allow balancing not only the individual power requirements, but also the grid electricity needs. The project achieved 138,000 hours of cumulative operation and produced almost 400,000 kWh of electricity and a heat output of 800,000 kWh. Further successes included no system failure during the trial, and fuel efficiencies of up to 90 percent and electrical efficiencies of greater than 30 percent. In short, EUVPP was an excellently executed project. However, one may ask, why are there not more virtual power plants, installed and working in the year 2010? They could represent one solution to overcome the peaks in supply and demand within our electricity grid.

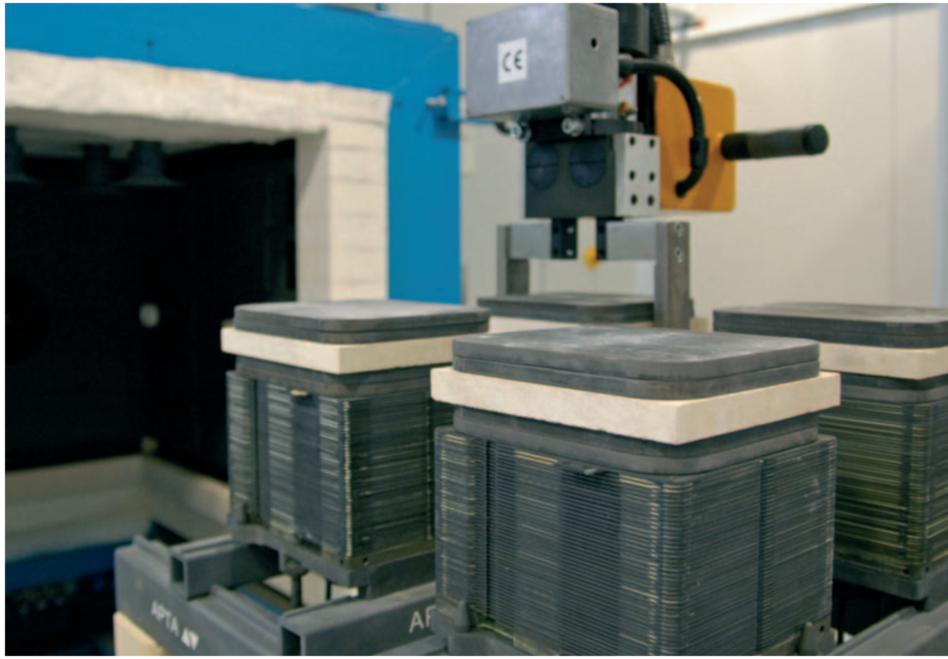
When asking experts, you get answers like: “We have achieved our target [to get the virtual power plant working], but time and funding were simply running out.” Or perhaps this idea is still too far ahead of its time and utilities do not want to give up their profit margins yet. After all, we are speaking about an independent power network with a decentralized structure.

Just imagine housing your own power plant in your basement. No new large power plants are required and electricity lines can be kept short or eliminated altogether. Scaling this concept accordingly, we calculate the need for hundreds of thousands of these units installed in one country, millions of them installed in Europe. Otherwise we would see no real grid stabilization effects. But who is capable of building this quantity of micro-CHPs at this time?

Once again we might pin our hope on Asia, specifically in Japan where sales of the so called ENE-FARM micro-CHPs based on polymer electrolyte fuel cells (PEFC) started in May 2009. 42,000 units with a power output of 300 W – 1 kW are projected be sold by the end of 2013 and 2.5 million units by 2030.[5] As stated in the Annual Report 2009 of Tokyo Gas Co., Ltd., one of

5) http://www.docstoc.com/docs/22923295/ENE-FARM-Residential-Fuel-Cells-Launched

Fuel cell stacks being manufactured automatically at a volume manufacturing plant from Ceramic Fuel Cells Limited, Victoria, Australia. The new plant located in Oberbruch, Germany was opened in October 2009 and has a design capacity of 10,000 stacks per year.



the six companies that launched the project, they are also working on doubling the power generation combining solar power with ENE-FARM. In addition, they target the construction of "smart energy networks" that integrate electricity, thermal, gas, and renewable energies to facilitate optimal area-wide networked energy use.[6]

Despite the progress that has been made in employing the residential micro-CHPs, many unresolved issues remain. At the moment, the systems are fuelled by natural gas which is converted into a hydrogen-rich reformate stream for later use in the fuel cell.

Hence GHGs are emitted and our dependence on fossil fuels is still in place. And what about the households without access to the natural gas distribution system? There is no doubt that the concept of micro-CHPs and virtual power plants are able to support a future hydrogen society, but unfortunately they do not necessarily promote renewable energy sources. There are other well-funded programs running at the moment that concentrate on bringing natural gas fed micro-CHPs to market around the world. We will have to carefully watch the results of those endeavors, but the challenge of sustainability will not disappear. We need to move beyond just ideas on how to improve the use of fossil fuels for the production of hydrogen, and put the emphasis on taking real action on the affordable and sustainable development of a hydrogen society. That said, come and join us now in fitting it all together.

6) http://www.tokyo-gas.co.jp/IR/english/library/pdf/anual/09english.pdf

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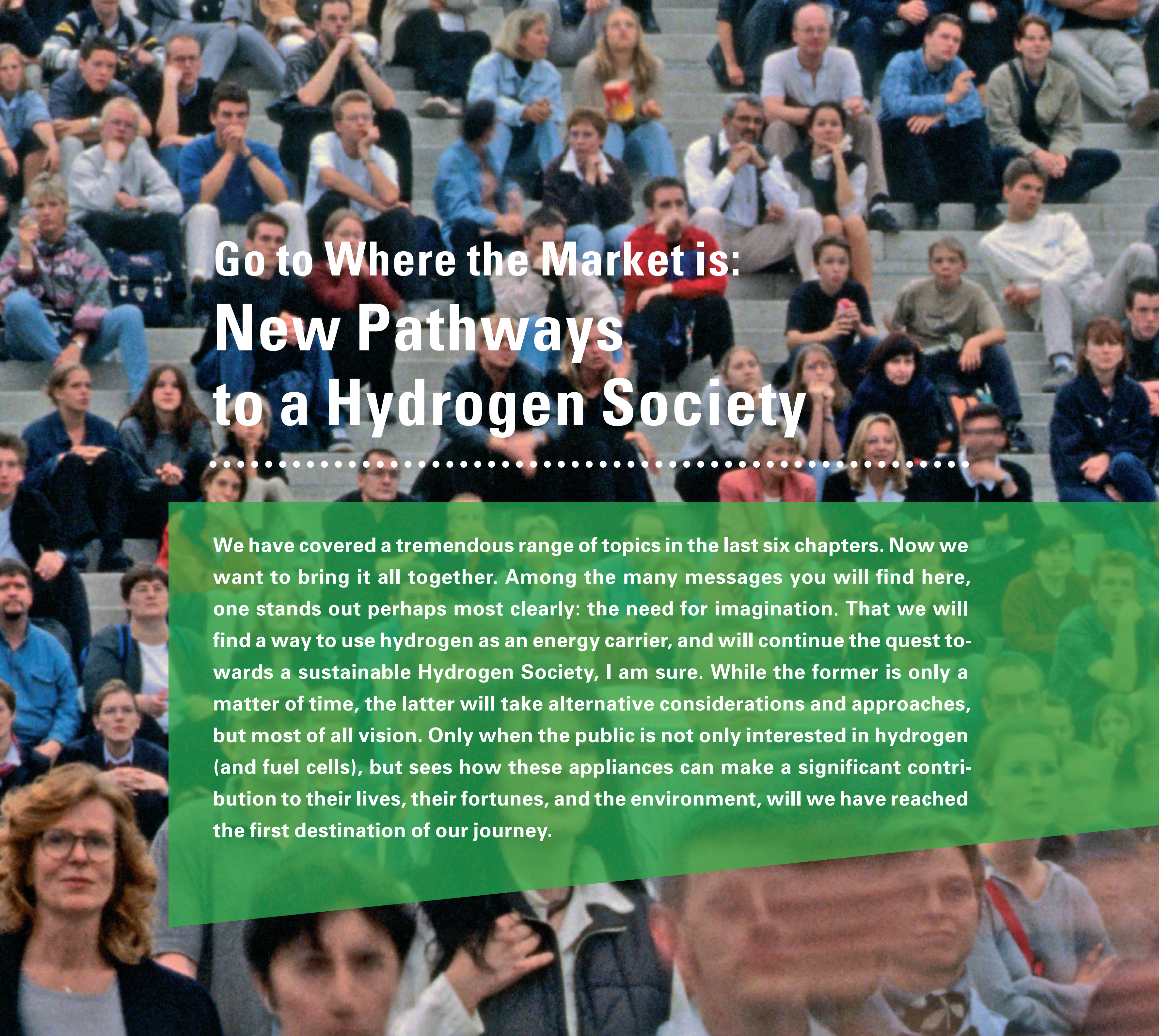
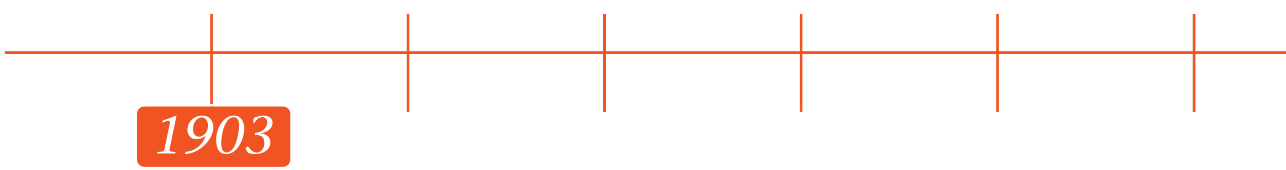


Go to Where the Market is: New Pathways to a Hydrogen Society

We have covered a tremendous range of topics in the last six chapters. Now we want to bring it all together. Among the many messages you will find here, one stands out perhaps most clearly: the need for imagination. That we will find a way to use hydrogen as an energy carrier, and will continue the quest towards a sustainable Hydrogen Society, I am sure. While the former is only a matter of time, the latter will take alternative considerations and approaches, but most of all vision. Only when the public is not only interested in hydrogen (and fuel cells), but sees how these appliances can make a significant contribution to their lives, their fortunes, and the environment, will we have reached the first destination of our journey.

A Question of Design or can 35 Locomotives Really Fly?

Figure 7.1



Let's start to expand your mind to a "new way of thinking" right away. It might be a little off track, but that is just one of the defining features of this book.

It is always a big step from demonstration projects to full-scale commercial products, and having the credibility to empower visions and awaken commercial interests is always a good idea to start with. For 23 years I worked for the European Airbus consortium. I therefore know how challenging it sometimes is to start from the drawing-board (as Airbus did in July 1967) and to conquer the world market in just a few decades of hard work. Today, Airbus (an EADS Company) is one of the leading aircraft manufacturers with the most modern and comprehensive product line in the world. They have managed to become an unquestioned part of the fabric of modern aviation. But with all their sense for unparalleled enginieering, could they have ever imagined to enable 35 locomotives to fly?

"No way!" is probaly your first guess. That 35 locomotives cannot fly is a globally accepted fact. An ancient locomotive from the former coal mining industry in Canada, for example, weighs, let us estimate, 16 tons (Figure 7.1). Thirty-five of such locomotives have a mass of 560 tons (560,000 kg or 1.234.589 lb). Amazingly, these 560 tons are equal to the maximum take-off weight of an Airbus A380, currently the world's largest passenger aircraft. Hence 560 tons can, in fact, fly. And in a rather elegant way, I might add. In the end, it is "only" a question of the molecular arrangement.

So why the comparison to locomotives, you might ask? Firstly, at the end of the 19th Century and at the beginning of the 20th Century, the railway, in its heyday, was the most modern transportation system on earth. Billions of Euros (Dollars) were spent on planning and building the necessary infrastructure and on making the locomotives more efficient. Secondly, at the same time – namely in December 1903 – the first controlled, powered, and sustained heavier-than-air human flight took place. Orville and Wilbur Wright brought their "Flyer" up into the air, powered by a 77 kg, four-cylinder four-stroke petrol engine with 12 horsepower (9 kW) delivered at the shaft. At that time, nobody could imagine that this little "jump" (the first flight lasted only for 12 seconds and was 36,5 meters long) would trigger the creation of an entirely new industry. In 2009, the total

1) http://www.iata.org/NR/rdonlyres/FB26BE30-7500-41F2-AB3E-7ACE49B7CD86/0/FactSheetIndustryFactsDEC09.pdf *(see page 130)*

2) http://boeing.mediaroom.com/index.php?s=43&item=1108 *(see page 131)*

3) http://www.dlr.de/en/desktopdefault.aspx/tabid-344/1345_read-18278/ *(see page 131)*

revenue of global commercial airlines alone amounted to US$ 456 billion with worldwide 2,178 million passengers carried and a transported freight of 35.2 million tons.[1] The Airbus A380 has a range of 15,000 km (8,000 miles) for a maximum of 853 passengers (depending on customer configuration). The first commercial flight took place in October 2007 with Singapore Airlines on the route Singapore – Sydney. The auxiliary power unit (APU) of the A380, providing electricity for the autonomous operation of the electrical and hydraulic systems (on the ground and in case of emergency), generates 2 x 115 V 400 Hz @ 120 kVA and is manufactured by Pratt & Whitney, Canada.

Just consider the imagination (and creativity) of the aviation pioneers at their time, including men like Clement Ader from France or the Germans Gustav Weisskopf and Otto Lilienthal, who could not in their wildest dreams have imagined what would have come from their inventions. The Wright brothers and Lilienthal were entrepreneurs running their own companies, driven by the desire: "… to add their bit to the eventual success of a future invention …" And they did this with great meticulousness – always documenting their work and progress in order to learn from their experience for further conclusions. Motivation and funding were completely self-determined. They never knew or needed tools like a roadmap.

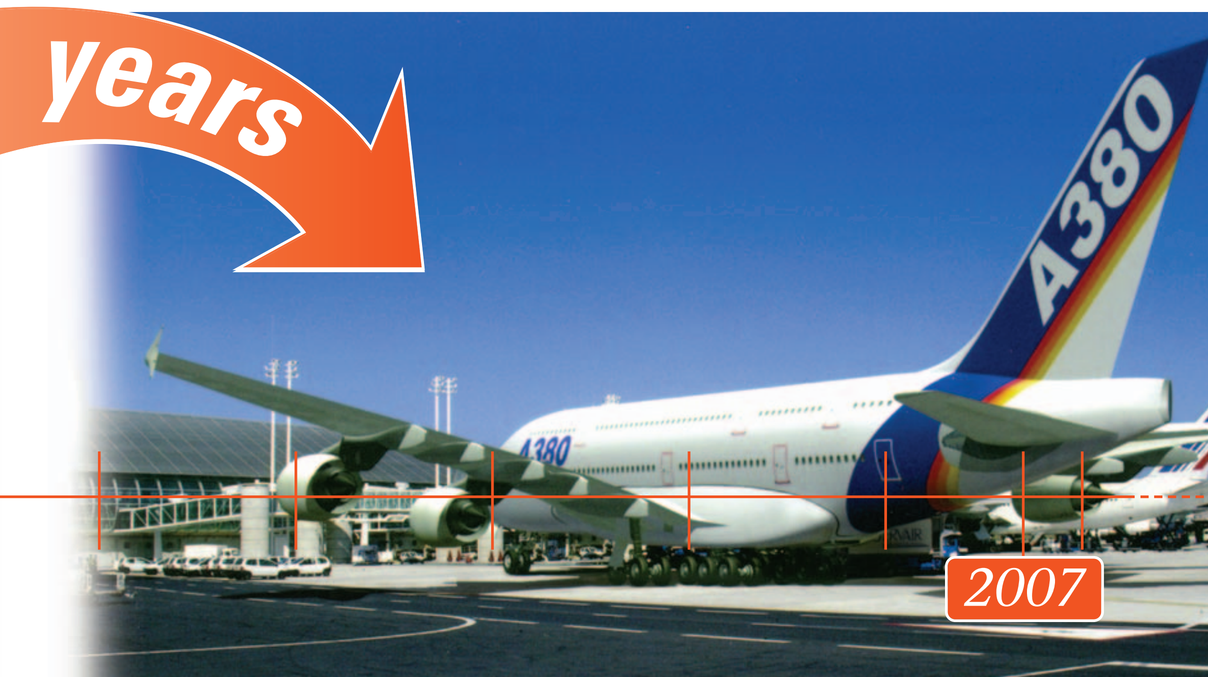
And now consider what can be developed using today's hydrogen and fuel cells technologies. For example, the Boeing Company is deploying rapid proto-

First powered flight:
Dec. 17, 1903
at a beach in Kitty Hawk, N.C.

Flight Distance **120 ft. / 36,5 m.**
Flight Time **12 seconds**
Passengers **0**
Max Take off Weight **352 kg**

typing to bring together an unmanned aerial vehicle with a liquid-hydrogen propulsion system that will be capable of flying for more than four days at altitudes up to 20 kilometers (65,000 feet), and is scheduled to make its first flight in December 2010.[2] Already in July 2009, Antares DLR-H2, the world's first piloted aircraft capable of making a complete flight cycle from take off to landing using only power from fuel cells, demonstrated its capability at Hamburg Airport, Germany.[3] It has been developed by the German Aerospace Center (DLR) in collaboration with its project partners Lange Aviation, BASF Fuel Cells and Serenergy. In November 2009, Antares DLR-H2 set a height record at 2,558 meters that proves it is possible to use fuel cell technology above 2,000 meters.

But deployment of hydrogen and fuel cells should not be restricted to the aircraft industry. Again, in my personal experience around the globe, only the mind sets the borders and limitations. The possibilities of hydrogen and fuel cells for us, and especially for future generations, are "far beyond our imagination". However, this development will not happen on its own; it takes a lot of clever minds, who are active, durable, and, above all, self-motivated. Hydrogen and fuel cells will one day offer new services that we have never dreamt of. And hopefully sooner than within the next 104 years. That said, let's bring my vision into play.



First commercial flight in 2007:

Singapore Airlines: Singapore – Sydney

Max. Range **8.000 nm / 15.000 km**

Wingspan **261 ft. / 79,5 m.**

Payload Max **853 Pax**

Max Take off Weight **560.000 kg**

Form and Function Combined:
The Personal Power Provider (3P+)

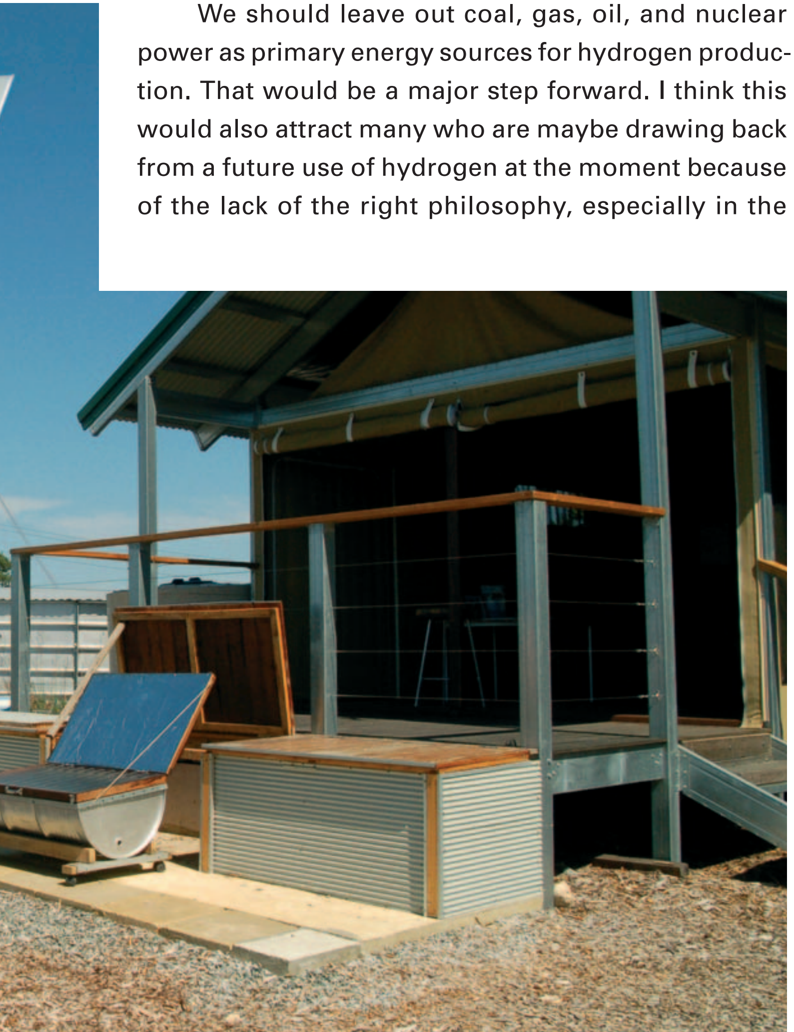
In the last chapter we have been able to make 35 locomotives fly. We then might as well carry on with some more imaginative pictures. The following ideas, however, are by no means to be understood as mandatory- or building-instructions. They are rather to be understood as a system of hints, or heuristics, to give us a way out of the dilemma in which we have placed ourselves. Albert Einstein already knew that we cannot solve problems by using the same kind of thinking we used when we created them. Thus starting on this pathway, we must wisely choose our new concepts of energy.

Our photo shows how different renewable energy sources can be utilized to generate electricity and hot water for a remote holiday home in Western Australia. At first glance it might look a bit strange, but we cannot afford to leave any stone unturned when it comes to explore possible renewable energy sources.

At the Environmental Technology Centre (ETC) at Murdoch University in Perth, Western Australia, many environmentally sustainable technologies, like climate-sensible buildings, renewable energy systems for power supply

Going one step further, we should eventually come to the point of understanding the advantage of hydrogen as an energy carrier. Here our ultimate target needs to be to employ processes, which produce hydrogen directly without the use of electricity and electrolyzers.

We should leave out coal, gas, oil, and nuclear power as primary energy sources for hydrogen production. That would be a major step forward. I think this would also attract many who are maybe drawing back from a future use of hydrogen at the moment because of the lack of the right philosophy, especially in the generation process. This may engage young people to realize these ideas, which is not an easy task at all.



The biggest disadvantage that these processes have is the lack of strong lobbyist support. This is understandable, as big coal, big gas and big oil, even big nuclear and big electricity companies do not want to give up their position. They are quite comfortable with things the way they are now. They have built up their monopoly positions over many decades, so why should they backtrack now. You have to think about the way they tear "their" raw materials out of the earth and you have to know, how they handle them until their products arrive at the final consumer, as described in former chapters. We should not only know, but also do better.

To come back to our thought experiment: Just imagine a sort of black box (Figure 7.2) whose size can be discussed and defined according to its intended use; and let us call this box the Personal Power Provider (3P+). As input, think of all renewable energies available at a given location, preferably the direct use of solar energy. Inside the 3P+ unit we make hydrogen, collect, convert, and store it. This hydrogen can then be used to power the remotest locations of our world. I am well

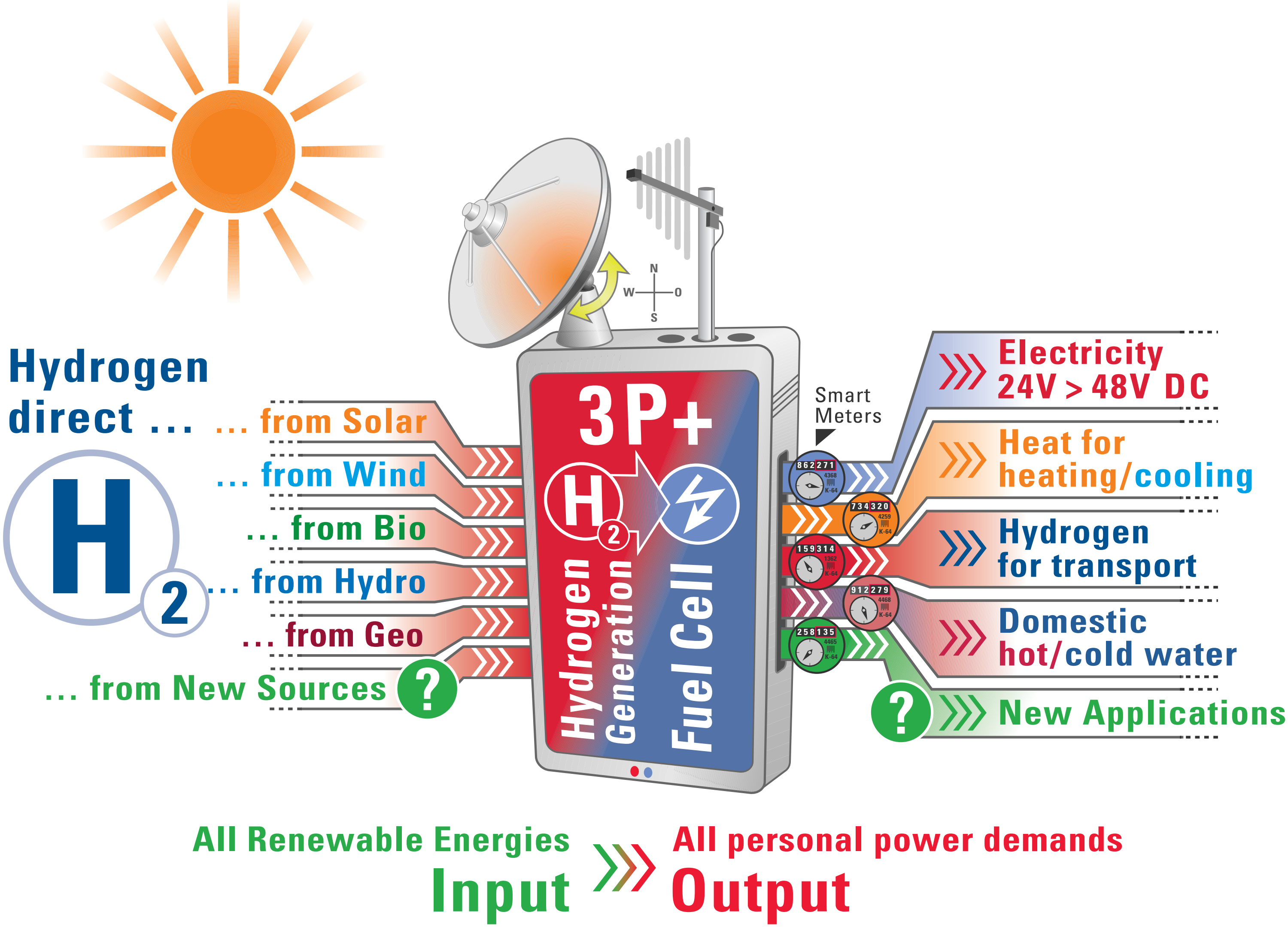
and water pumping, aquaculture systems, organic waste management, and permaculture have been combined to form an integrated operating demonstration system.

aware of the fact that these processes have to be developed; they presently either exist only in small-scale laboratory trials or do not at all.

However, with a fuel cell inside the 3P+ system we make electricity, and by the nature of the process this is between 24-48 V DC. Not only that, the heat and water, needed and dissipated in the process of first hydrogen production and second electricity production, are also stored and commercially traded as commodities. The DC electricity is supplied and used in close proximity to the location of the 3P+ system directly. In doing so, we can avoid immense losses, as we do not have to transport electricity over long distances and also not have to convert it from DC to AC back and forth in the charger units, lighting, TV sets, laptops etc.

One future day, the hydrogen has to be utilized as ultimate energy carrier to meet all personal power demands for electricity, transportation, heat and domestic water simultaneously in an inexpensive and environmentally compatible way. Downscaled using nanotechnologies, and scaled up in a modular fashion from mW to MW, the Personal Power Provider can be adapted individually to the necessary output on the spot. The 3P+ units can be installed in family homes, factories, public facilities and small villages where they form a cluster of decentralized energy systems. In this way, supply will always meet demand, while at the same time making optimum use of the renewable energy sources available. The 3P+ might even be carried on the body one day, so that electrical equipment can be recharged at any time, or they can be used to supply the remotest of buildings. As a result, the Personal Power Providers are the key for decentralized, personalized mass energy markets, increasing access to energy and increasing convenience at the same time. The user and the producer of energy becomes one and the same. That means: Power to the people (and that not only for the western world).

As our own way of thinking changes, technology itself could very well change dramatically, and, in doing so, expand possibilities before us. We must learn to work together to develop effective strategies for achieving this transformation. And as far fetched as the idea of the 3P+ might sound, in a sense, we have already introduced it in a slightly different version in chapter 6.2: the micro-CHP based on fuel cell technology.



Data Source: own investigation

Figure 7.2

The Personal Power Provider (3P+)

scalable from mW to MW

Fitting it all Together:
On the Way – to a Real Hydrogen Society

Humanity has long dreamed of exploiting hydrogen as a safe, clean and, virtually unlimited energy vector when produced from renewable sources. But while key milestones have been achieved, skeptics still question whether a working Hydrogen Society will ever be possible. And they might be correct. To date, we have heard a lot of rhetoric on the importance of sustainability goals, but we have taken few meaningful steps to commit seriously to a long term plan to reach sustainability – with or without hydrogen as an energy carrier.

As shown throughout this book, many of the economic and environmental problems we face today result from our fossil fuel dependence. And as demand increases, future fighting over the vanishing resources looms and concern about GHG emissions grows. There is no doubt that this situation can only be overcome by fundamental changes in our way of energy production and distribution: converting to a decentralized system, harvesting all renewable energies, and making hydrogen the primarily energy carrier of our future. The solutions may not always be simple, but they are certainly not beyond our reach. A business-as-usual-approach, however, will not work. It will only waste time, which we are critically short of. Hydrogen is an appealing option for powering our future for several reasons. As the most abundant element in nature, it can be made from a virtually unlimited range of chemical feedstock including natural gas, coal, nuclear, biomass, wind, and solar. To make it, external energy is required. Once you have created hydrogen from renewable energy, it can be used as both a storage and transmission medium. To create a real Hydrogen Society, however, special attention has to be paid to the production of hydrogen. Only when it is made in an environmentally benign fashion can hydrogen be used as a universal and non-toxic energy carrier which does not create any harmful emissions. The technology is advancing quickly; the renewable energy sources are there. What else do we need?

First of all, the investment would be substantial. A Hydrogen Society would displace all the conventional power plants with all the fossil fuels they consume and all the losses and emissions they produce today. We have blazed a path to an energy system that is exceptionally inefficient in the use of its key source with little regard for the long-term consequences and its true costs (for example for acid rain, oil spills, climate change). There may be even more impact to expect, unknown to us today. When arriving at this point, we have to think: What is our next move? To find the right answers, we have to consider some additional parameters. I do not claim to know all of them, but would like to suggest some nonetheless to the concerned citizens, engineers, and decision makers. One parameter is the still growing energy demand in countries like China and India. The population of both countries was not significantly effected by the financial crisis of 2008. They still have annual GNP growth rates in two digits. At the same time, these nations are repeating the mistakes made in western countries and elsewhere in terms of energy production and distribution. Fossil fuels are simply too cheap. And they are presently there, but don't ask for how long.

The next parameter is the concern about our environment. Here I am referring to the well-known climate change issues, mainly caused by the increasing amount of CO_2 in our atmosphere. Most of us, but certainly not all of us, know that coal power plants are by far the biggest CO_2 producers worldwide. This is true for any country, developed or not. Regardless of the standard of living or the size of the gross national income, we are using an energy system based on 19th century technology. But how do we act on this knowledge? Just one example: Xstrata Coal, the world's largest exporter of thermal coal and the fifth largest producer of hard coking coal, with headquarters in Sydney, Australia, reported in the beginning of February 2010 that its coal production rose 11 percent to 95.2 million tons in 2009. The stakeholders have been quite happy about this result, I imagine.

What is not in question, though, is that "natural" resources like coal, gas, oil, and uranium are being depleted. These resources should, in my opinion, be better left to future generations for sensible purposes such as pharmaceutical or food production rather than being used to satisfy our present energy needs. Does it make sense when you explain to someone that we presently drill for oil in the Middle East, sent it in huge ships around half the world, refine it somewhere else, and sent it by truck or rail to your filling station? But that's the way it is. So why should we dare to change it?

The last, and not at all the least parameter, is the large number of people, who have no access to electricity. This is not the fault of those 1.7 billion inhabitants of our planet. Their mistake is only that they were born in the "wrong" region of the world. And they were born at a wrong time, too. Just around 150 years ago, nobody in the world had access to electricity. And nobody missed it at all. The same applies to petroleum products, which we are used to buy daily at our filling station in the form of petrol or diesel. How arrogantly we have developed our relationship with our resources. It took millions of years to form them.

This former ignorance of electrical power and crude oil did not effect eminent cultural developments like building the pyramids in Egypt, erecting Stonehenge in England, discovering book printing, creating gun powder and chinaware in China. Neither electricity nor crude oil was necessary to making discoveries around our universe, in mathematics, navigation and physics like they did in ancient Italy, Greece or Germany. Or think of the works of Bach and Beethoven, all created without even knowing electricity. On the other hand, the Beatles, to me musicians of a similar calibre, needed the moving electrons for their amplifiers and recording equipment. They could not have become so famous nor would the rise in our standard of living, the missions to the Moon or to Mars have been possible without electricity.

The real question to ask at this point is whether we want to continue to harm our planet because we are familiar and comfortable with the basic structure of power supply, or shall we press on with much greater urgency to establish a society that embodies a framework of thinking and living sustainably. This would mean that we would have to free ourselves from the electricity, oil and gas grids. I propose an approach that takes a global look and gives us freedom to think freely.

This outlook will not necessarily be endorsed by those who are presently "ruling" the existing system. These managers have scouts, observers, and scanners, to say it politely, infiltrating associations, institutions, administrations and government agencies at many, if not perhaps at all levels. They have the funds, at least at this time. They know exactly what they are doing and they watch the progress rather carefully. Their reach extends so far that they are able to write important paragraphs of legislation, as it was the case with the German feed-in-tariff laws. There are many more examples in all countries. This work is today looked upon as being legal, and it is called lobby work; I call it "lobbyismus". In my English-German dictionary there is even an entry for that: "To lobby a bill...". Good to know that this has already been recorded.

Powerful lobby groups represent the people engaged in survey, exploration, extraction, transportation, conversion and distribution of fossil fuels, as well as those, who are converting it into electricity or fuel for transportation. They are all doing a great job, I do not want to blame any of them for anything. But when it comes to the future, when it comes to handing over our globe to the next generation, their actions may be questioned.

But how can we escape from this tangle?

Please do not ask me for exact guidelines. I can only ask you to analyze the status quo and try to understand and maybe follow my ideas, which are documented in this book. It took me 15 years to gather this valuable information all over the world. My goal was and still is today, to bring hydrogen and fuel cells to the worldwide marketplace.

I enjoyed every day of this time, and still do it today. I admire all those researchers, designers, entrepreneurs and even laymen who are working in this field and whom I have met over the years. I am full of hope that we all will see, at least, the rise of another, much better energy reality. When you consider all aspects, it is in fact not too difficult to achieve those changes. But it needs both: bravery and endurance.

That said, I would suggest the following key steps that can bring us all to a Hydrogen Society within the next few decades. Hopefully sooner than too late.

Be careful with definitions: H_2 Economy versus H_2 Society

Many of us have heard the expression "Hydrogen Economy" for many years. Even today, this term means only a sort of 'green painting' of the existing electricity and fossil fuels system. It does not help much, when the hydrogen suddenly turns green only in the moment it is fuelled into a car (or laptop), when you find out that the hydrogen originally comes from a steam reformer and is made from natural gas, or when you use propane or methanol as energy carrier (both presently of fossil origin). This sort of hydrogen 'green painting' as it is used today will not last forever, it will be washed away by reality checks. And these checks will come soon, if not now, then from the next generation, who is getting more and more eager to change our energy system.

Hydrogen is not really used commercially by the end consumer at this time. The handful of hydrogen cars and their fuelling stations are more "for show" or to fulfill sponsored funding schemes, and cannot stand alone. Enough promises have been made, and now I would like to see the stage open for more action in the right direction. The curtain must be raised!

New attitudes towards our existing energy system, which have to be based on careful, unbiased research, are required to implement a Hydrogen Society which utilizes clean hydrogen as its sole energy carrier. But this will not come on its own, and even sound technological know-how alone is unlikely to solve any of our problems. We need the willingness of the global population to make the necessary changes, and must be able to fulfill their desire for sustainable energy self-sufficiency. I have seen young people on all continents resigning and turning away from hydrogen and fuel cells because they could not hear it all again from the same people. We need to give them a hand to carry on with the topic. There are immense workloads for research and development ahead of us. Many challenges have to be tackled and solved; many new ideas defined, tried out and eventually realized. The components and tools for building a real Hydrogen Society lie before us. Real green or even golden hydrogen is entirely achievable! And as we move forward, we will likely create not only new and different applications, but new services as well.

Use the sun as it is intended to be used …

… as the greatest natural resource supplied by nature. The power of the sun was able to create the conditions we now see on Earth. Why should we question this source? Direct solar hydrogen production works with the use of concentrating solar energy. Water and sunlight are the only inputs. In spring and summer, this technique would produce enough hydrogen to meet fuel demand in most of the countries; and in equatorial regions, all year round. With better understanding of the technology, better results are foreseeable. Much of the progress depends on the enthusiasm put into its development. Do not give up too early. Do not set your targets too low. The higher, the better! Do not hesitate when the ideas make sense to you!

Do not put all of our eggs in one basket

The successful global introduction of the often quoted Hydrogen Society rests completely on origin of the energy carrier. That is the most decisive point. As we have learned in this book, there are many ways to make hydrogen, but only some of them, namely the direct use of renewable energy sources, are environmental sustainable. The fewer steps we have in the clever conversion, the better the overall results. And why not make the energy carrier only when and where we need it?

The challenge is to implement a mix of renewable energy sources that offers the highest efficiency in producing clean hydrogen at the lowest cost. Because each location has unique geographical properties, a Hydrogen Society might look quite different in different regions, and would always depend on local resources! The combinations are virtually limitless, and will ensure the reliability of the supply of hydrogen. Electricity, which plays such a critical role in our present time, should be a minor actor in the production of hydrogen. In this context, put the electrolyzers aside and make hydrogen more cleverly, greener, and more efficiently. We will not be able to even start a Hydrogen Society, if we stick too close to the production technologies of today.

If you need electricity, make it only at the end

In order to create a real, sustainable Hydrogen Society, hydrogen must become a common commodity which is used and traded close to its point of production. Distribution costs could be unmanageably large when trying to transport hydrogen in either liquid or gaseous form from point A to point B. In regions with dense populations, pipelines might become a suitable option for delivery, but once again, those decisions should always be made by examining local conditions and requirements. It will all look different in urban centers to rural villages. Decentralized hydrogen production facilities, which you might want to call micro-CHP systems (chapter 6.2) or Personal Power Providers (chapter 7.2), can supply, according to their size and deployment, houses, villages, and communities with a sufficient amount of clean hydrogen. Hydrogen not needed at the time of production is stored and can then be used upon demand by the users for electrification, transportation, heating/cooling and convenience.

Think locally, act locally, incite globally

Fuel cells are a logical extension of our Hydrogen Society, providing electricity, heat and water on demand when fuelled by clean hydrogen. The absence of combustion and moving parts makes them the most quiet, efficient and soon most reliable energy converter we have! As long as clean hydrogen is available, scalable fuel cell stacks can provide the exact amount of energy needed, and are even responsive to changing electrical loads. It is hard to imagine all the uses such converters/generators may eventually find. All outputs need to be utilized at the point of use. Distributed generation with central control might contribute to meeting peaking demand with sales of surplus energy and thus act as a virtual power plant, but this should not be the first goal. The main aim is to keep the generation and distribution network as small and efficient as possible. Any transmission of electricity is aligned with losses, not to ignore the continued dependence on the grid.

All the advantages of fuel cells, first and foremost the emission-free production of electricity, should be utilized in connecting new markets for heat/cooling and for domestic water. Together with truly "golden" or at least "green" hydrogen, fuel cells can be used as personal power systems in order to run our daily lives. This can be achieved using a global strategy which does not exist today. We have not only to consider global market demands, but also environmental aspects. It is worth the effort.

The "Yes, we can" slogan could also be appropriate for those researchers who are ridiculed because they work on optimizing and refining processes such as converting biomass to hydrogen. Mostly due to lack of understanding and the commensurate lack of funding, these projects have not been continued with as much vigour as they deserve. I have seen hydrogen made from algae in 1995 already, but the researchers engaged in this topic have been abandoned because of external pressure from the system. At that time, the resilience of the inventors was unfortunately not high enough. But times are changing. They will find their way!

Although the investment is high, the challenges appear to be immense, it is important to remember that renewable energy sources used for hydrogen production are free. When all the costs of our current energy system are factored in at real values, a Hydrogen Society would be a bargain. New production methods using better technology would sink production costs substantially, so that projects whose realization failed in the past because of these high costs, can be considered, planned and finally realized. Existing industries can secure many jobs with the installation, operation and maintenance of the decentralized energy network. Moreover, extensive and different components necessary to run a Hydrogen Society provide, on the long-term, orders for many suppliers, especially for small companies known for their high innovation potential. These jobs will not only be accrued in the "Western" world, but also in underdeveloped regions. New jobs and new opportunities will arise worldwide.

Considering the political situation today, in 2010, energy solutions are very much in demand. But from whom do you think they will come? This leads us to the two pictures in the introduction. If we are not taking the "situation into our hands" I am afraid nobody will do so. At this time, we all still have the chance. New targets, far beyond our current imagination, can be achieved. Thank you for taking up the lead and to making it happen.


8

And in the End:
Final Considerations and Future Prospects

In the early 2000s hydrogen and fuel cells were seen as potential candidates for addressing problems ranging from energy independence and climate change to local generation of electricity. But today, the initial hype has somehow subsided, and companies are cutting back not only on activities, but also on investments in hardware and software. The goal seems to have shifted from exploring possibilities that do not currently exist, to remaining in a state of market observation. Additionally, much money is being spent by public authorities and associations to determine what "… the others …" in the field of hydrogen and fuel cells are working on. A schism that continues to deepen and broaden within most areas of the once rapidly emerging technology.

And in the End:
Final Considerations and Future Prospects

To implement hydrogen and fuel cells, more and more organizations with new websites and somewhat similar objectives are being founded, meetings at various levels organized, agendas and protocols published, and many subventions are applied. But when you look closely, everything sometimes appears to move in a circle. At the end of the day, most of what has been recently worked out has been said and well-documented before. Valuable time and money have been lost, and, in most cases, no results are realized . Unfortunately, it looks like that’s going to continue for the foreseeable future.

Despite much effort, there are no considerable numbers of commercial products on the market that directly enhances the public status of hydrogen and fuel cells to date, aside some educational equipment and toys. Specifically, three trends can be identified that do not necessarily lead to global fuel cell commercialization:

Firstly, more money than ever is invested in low budget solutions. Companies work on highly subsidized H_2/FC powertrains for golf carts or forklifts, for example, without changing much on the vehicles themselves. Very nice indeed, but the possibility of a technological breakthrough is more than limited here and - to be honest – is part of the problem rather than being part of the solution.

This brings us to the second trend: The work on “replacements”. Here H_2/FC shall make up for existing technologies, such as internal combustion engines in cars or batteries in laptops and cameras. It is naturally quite difficult to break the lock-in of the already well-established technologies. And the challenge is made even more difficult by the apparent lack of real progress.

The established industries are not necessarily waiting for us. Why should they?

Last, but not least, the number of heavily subsidized projects which are launched with immense PR has steadily risen over the years. The trance, however, is rudely broken as soon as research funds or commercial interest dwindle and often the project is then called "successfully completed" and shut down. The know-how gained is of course lost in the process.

In 1999, for example, the first public hydrogen fueling station worldwide was opened at Munich Airport, Germany, as part of the hydrogen demonstration project H_2argemuc. In 2006, the project came to an end and the history-charged fueling station was dismantled.

As we dig more deeply, similar examples can be found: Euro 37.5 million were allocated by the European Commission from 2003 to 2009 for the so called CUTE (Clean Urban Transport for Europe) and HyFLEET: CUTE projects to support nine European cities in introducing hydrogen powered fuel cell and later also hydrogen powered combustion engine buses into their public transport system (an "impressive" number of approximately three vehicles for each city). After two

See also page 101

years of the CUTE project the Stockholm and Stuttgart buses were passed to Hamburg. Now owning nine buses in total, Hamburg sold itself as the city with the world's largest H_2/FC bus fleet. It's strange but true. It was rumored that it was too cold and humid in Stockholm and too hilly in Stuttgart, but that's another story. The projects, however, have come to end and only Hamburg seems to take the future of H_2/FC vehicles seriously.

Starting 2010 Hamburger Hochbahn AG (HHA), the Hamburg transport authority, will take delivery of ten new Mercedes-Benz Citaro FuelCELL buses and another 20 Mercedes-Benz B-Class F-CELL cars.[1] Making the purchase even more significant, from 2018 onwards the HHA plans to place 60 to 70 Mercedes-Benz Citaro FuelCELL buses on the road per year instead of buying new diesel buses. Still a long way to go, though, and the competition is intense. In March 2010 two Mercedes-Benz Citaro G BlueTec Hybrid buses have been acquired for a different field test by the HHA. This time the buses are driven by electric wheel hub motors that obtain their electricity not from fuel cells, but from one of the world's largest lithium-ion batteries ever to be used for a mobile application.[2] But whether or not these particular H_2/FC projects are on the right track, they often repeat themselves in a predictable way and hardly fulfill the needs of a "real world" scenario. Where are the ideas that will ignite a green fleet revolution which would accelerate the technology after decades of research and development?

Ironically, the production of hydrogen is hardly recognized in most of the support programs. But just as you cannot have a tea party at which there is no tea, you cannot have a clean transportation system at which there is no "green", or better "golden" hydrogen. But once a movement is gone, it may be gone for ever.

Certainly, not everyone agrees that hydrogen and fuel cells should play a prominent role in our energy future. New projects for sustainability that outperform the above mentioned H_2/FC projects appear nearly everywhere. The investments made by governments and commercial enterprises may appear astonishing. But they are not, as they are based on a strictly calculated return of investment (EROI), and unfortunately, they maintain and even expand the existing energy system. Here are only five examples:

1) http://www.h2euro.org/2009/11/2080

2) http://www.benzinsider.com/2010/03/

1. Euro 17 billion (US$ 22 billion) Masdar City project near Abu Dhabi[3]

The renewable energy program in the Emirates has made international headlines with the Euro 17 billion Masdar City project near Abu Dhabi, which aims to be the world's first carbon-neutral, waste-free urban community. Masdar, the operating company, is already investing in solar panel manufacturing plants in Germany and the UAE. It is also in partnerships to develop the UAE's first utility-scale solar power plant and clean energy projects including an integrated hydrogen power facility and a carbon capture and storage system. The solar project has a modular design that could be expanded from an initial 100 MW (Shams 1) to as much as 2,000 MW over several years.

INVESTMENT IN ENERGY (Example 1)

2. Euro 30 billion (US$ 40 billion) 'Green Grid' project[4]

Nine North-western European countries are planning a giant underwater energy grid in the North Sea linked to wind farms, tidal power stations, and hydroelectric plants. Thousands of kilometers of high-tech energy cables are set to be laid on the seabed of the North Sea. The Euro 30 billion project will mainly be funded by energy firms, and is expected to produce 100 GW of power.

The EU hopes to generate a fifth of its electricity needs from renewable energy sources by 2020; a move which, according to their planners, requires new, modern energy grids capable of absorbing the fluctuations of wind and solar energy.

INVESTMENT IN ENERGY (Example 2)

3. Euro 400 billion (US$ 533 billion) DESERTEC Project[5]

A German-led consortium plans to build a huge solar farm in North Africa and ship electricity back to Europe. The project involves a consortium of about 20 firms including Siemens, Deutsche Bank, and energy companies like RWE, and will cost an estimated Euro 400 billion. This project makes use of relatively low-tech solar thermal power, using mirrors in the desert to heat up water which

INVESTMENT IN ENERGY (Example 3)

3) http://www.thenational.ae/apps/pbcs.dll/article?AID=/20091212/BUSINESS/712129931/1005

4) http://www.businessweek.com/globalbiz/content/jan2010/gb2010017_256132.htm

5) http://www.businessweek.com/globalbiz/content/jun2009/gb20090617_792023.htm

drives turbines in local power plants instead of arrays of high-tech photovoltaic cells. As well, the DESERTEC plan requires a new grid of high-voltage transmission lines from the Maghreb desert to Europe to provide around 15 percent of Europe's energy needs.

4. Euro 15 billion (US$ 20 billion) nuclear deal between UAE and S. Korea[6]

INVESTMENT IN ENERGY (Example 4)

The United Arab Emirates awarded a South Korean consortium a prized Euro 15 billion deal to build four 1,400-megawatt nuclear reactors. The Korean consortium includes Samsung, Hyundai and Doosan Heavy Industries. Japan's Toshiba Corp. and its Westinghouse subsidiary will also play a role. The Emirates plans to begin construction on its nuclear plants in 2012.

South Korea has never before exported a nuclear power plant. The Asian country's Ministry of Knowledge Economy said the deal is expected to bring South Korea a total of about Euro 30 billion from building and assisting in operating the nuclear reactors.

5. Euro 7.4 billion (US$ 10.6 billion) Baltic Sea gas pipeline[7]

Nord Stream AG was granted permits to build a pipeline to transport natural gas under the Baltic Sea from the Russian port of Vyborg to the German port of Greifswald. Construction of the pipeline is due to start in spring 2010. Once completed, the 1,200-kilometer (750-mile) pipeline is expected to carry 55 billion cubic meters of gas a year. Russia's Gazprom holds 51 percent of the joint venture. German energy companies E.ON, Ruhrgas AG, and Wintershall AG each hold 20 percent, and the Dutch company Nederlandse Gasunie NV holds the remaining 9 percent.

INVESTMENT IN ENERGY (Example 5)

6) http://www.businessweek.com/ap/financialnews/D9CRP5J02.htm

7) http://www.businessweek.com/ap/financialnews/D9CSD74O0.htm

Are these examples standing for a promising development of a decentralized energy system, and for hydrogen and fuel cells? I do not think so.

Realizing a new approach of energy supply and generation is something we must all do, and the benefit will belong to every person on our small planet. As recently as December 2009 we could track the failure of the UN's climate summit in Copenhagen. As the summit showed, sustainability doesn't begin and end in the "corridors of power". It starts with us and people like *Antonio Tuja, Jr., international director of the non-governmental Manila-based IBON Foundation* who made it quite clear in an interview in the No. 02 2010, Volume 51, February 2010 issue of the D+C Development and Cooperation journal:[8]

"The North's destructive model ..."

"... It does not make sense to try to resolve the major environmental crisis with binding emission targets ... We need a new development paradigm, a model of development that would lead to a healthier world. China and India are following the North's destructive model of industrialization. Their strategy of GNP growth at all cost is not sustainable, but nor is the style of rich nations. On the other hand, it is much easier for rich nations to cut emissions than for poor ones that do not have the same technical options and do not have access to the same range of commodities. ... I'm thinking of an economic model that does not emphasise individual incomes and their personal consumptions. We must look at people's quality of life in more comprehensive terms, taking account of health, creativity, skills and values as well as the welfare of communities. Such a model would obviously take into account a sound environment. A consumer society of the type you have in Western Europe or North America is neither desirable nor environmentally possible all over the world. Consumerism is not sustainable; it is as simple as that. Therefore, change will be more difficult in rich nations than in the developing world, because in the North, you are already used to consumer lifestyles..." Asked about the role governments are playing, Tony said: *"As long as talks focus only on emission targets and do not take a more holistic view of things, including, for instance, climate debt, they will not budge. The rich nations have been polluting the atmosphere for decades, they are responsible for*

8) http://www.inwent.org/ez/articles/166521/index.en.shtml

the climate change we are witnessing today ... We need a new development paradigm for all of humanity, including the rich nations. The Kyoto Protocol, as it is being applied, is really about keeping the matters as they are and trying to boost some kind of cleaner technology. It is not about change in rich nations, it is not about climate justice. If we were dealing with a more convincing proposal, one that was geared to a more holistic development model, you would see movement...!"

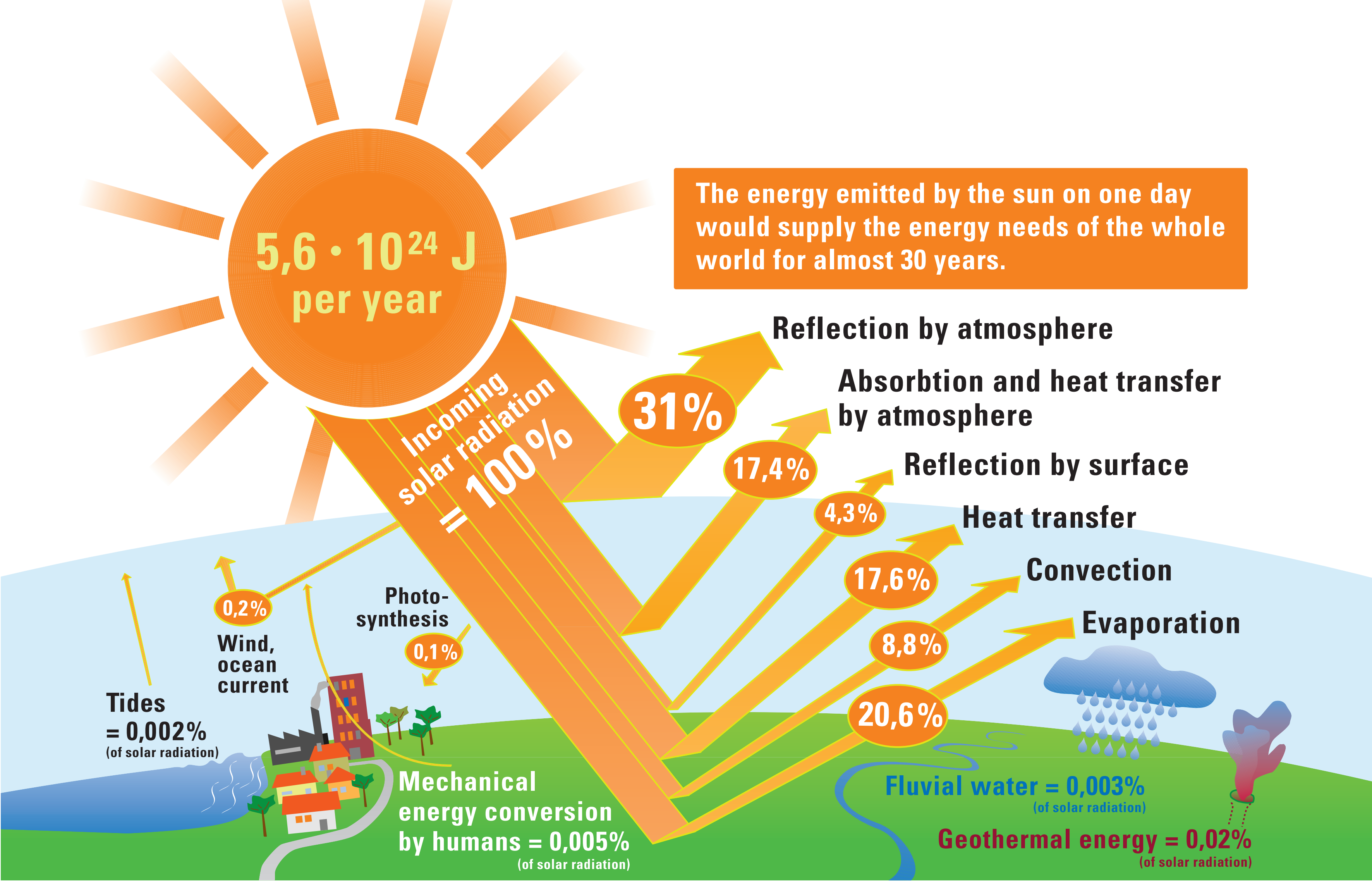
I could not have said it any better. We have certainly reached a point in H_2/FC technology development where the tools to provide households and industries with clean and sustainable energy are available. Now the challenge before us lies in pushing speculative ideas beyond the comfort zone of public policy and utilities.

It is difficult today to fully appreciate how to best cope with the current situation around the globe. And yet, there is nowhere else left to go. With the effects of global warming, what will we do? With fossil fuels depleted, how will we live? As Galileo Galilei (1564 –1642) already knew: *"The sun, with all those planets revolving around it and dependent on it, can still ripen a bunch of grapes, as if it had nothing else in the universe to do."*

There is a lot of truth there and more than a little wisdom. And what better challenge to use it for our golden hydrogen or even better, for a golden Hydrogen Society!

At the end of this book the concerned citizen may ask for an advice: What should I do next? If you should ask me, frankly: I do not know the whole answer myself. The whole issue about our all energy future remains fascinating and exciting. The main thing I would suggest to you is that you remain on guard! Use your utmost common sense and ask yourself: Why should I do this or that, why does the system ask me to do something in this way or that way? Please stay alert, have a look at the books and websites we are recommending, and check regulary our own website:
www.hydrogenambassadors.com

Thank you for reading this book and spreading the word about it.



Data Source: www.physik.uni-muenchen.de, Staatsministerium für Wirtschaft

Figure 8.1

Earth's Energy Balance

including Energy Conversion by Humans

Bibliography

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▷ All other photos: The author Arno A. Evers

Books, Journals and Magazines

▷ Arbeitsgemeinschaft Energiebilanzen e.V. Energieverbrauch in Deutschland im Jahr 2008. Berlin, Germany 1/2009

▷ Arbeitsgemeinschaft Energiebilanzen e.V. Energieflussbild 2008 für die Bundesrepublik Deutschland in Petajoule. Berlin, Ger. 09/2009

▷ Arbeitsgemeinschaft Energiebilanzen e.V. Energieflussbild der Bundesrepublik Deutschland 2007. Mio. t Steinkohleneinheiten (SKE). Berlin, Germany 09/2009

▷ Arlt, Bodo. Bodo's Power Systems. Laboe, Germany 02/2010

▷ Barbir Frano. PEM Fuel Cells. Theory and Practice. Elsevier Academic Press. San Diego, USA 2005

▷ Benesch Wolfgang. Energien für das neue Jahrtausend. RAG. Essen, Germany 2004

▷ Black Edwin R. Internal Combustion: How Corporations and Governments Addicted the World to Oil and Derailed the Alternatives. Griffin. New York, USA 2006

▷ Bölkow Ludwig. Der Zukunft verpflichtet. Erinnerungen. Herbig Verlagsbuchhandlung GmbH. Munich / Berlin, Germany 1994

▷ Bölkow, Ludwig. Entscheidungen für eine langfristige Energiepolitik. Vortrag von Dipl.-Ing. Dr.-Ing. E.h. Ludwig Bölkow vor dem Peutinger-Collegium in München am 25. März 1982. EAT. Ottobrunn, Germany 1982

▷ Bossel Ulf. The Birth of the Fuel Cell 1835 – 1845. European Fuel Cell Forum. Oberrohrdorf, Switzerland 2000

▷ Bockris John O'M. and Veziroglu Nejat T. with Smith Debbi. Solar Hydrogen Energy – The Power to Save the Earth. Macdonald & Co. London, UK 1991

▷ BP p.l.c. BP Statistical Review of World Energy June 2008. London, UK 2008

▷ Busby Rebecca L. Hydrogen and Fuel Cells: A Comprehensive Guide. Pennwell Corp. Tulsa, USA 2005

▷ Campbell Colin J., Liesenborghs Frauke, Schindler Jörg and Zittel Werner. Ölwechsel!: Das Ende des Erdölzeitalters und die Weichenstellung für die Zukunft. Deutscher Taschenbuch Verlag. Munich, Germany 2007

▷ Cleveland Cutler J. und Morris Christopher G. Dictionary of Energy. Elsevier Science & Technology. Oxford, UK 2006

▷ Dauensteiner Alexander. Der Weg zum Ein-Liter-Auto. Springer Verlag. Berlin, Germany 2002

▷ Deffeyes Kenneth S. Hubbert's Peak: The Impending World Oil Shortage. Princeton University Press. Oxfordshire, UK 2001

▷ Ditfurth Hoimar v. Im Anfang war der Wasserstoff. Deutscher Taschenbuch Verlag. Munich, Germany 1981

▷ Droste-Franke Bert, Berg Holger, Kötter Annette and Ziesemer Thomas. Brennstoffzellen und Virtuelle Kraftwerke: Energie-, umwelt- und technologie-politische Aspekte einer effizienten Haus-energieversorgung. Springer Verlag. Berlin / Heidelberg, Germany 2009

▷ Dudenhöffer, Ferdinand. Automobilindustrie in Asien. B&D Forecast GmbH. Leverkusen, Germany 2003

▷ Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. BMU-Brochure. Erneuerbare Energien in Zahlen – Internet-Update. Berlin, Germany 12/2009

▷ Geitmann Sven. Wasserstoff und Brennstoffzellen – Die Technik von morgen. Hydrogeit. Kremmen, Germany 2004

▷ Geitmann Sven. Erneuerbare Energien und Alternative Kraftstoffe. Mit neuer Energie in die Zukunft. Hydrogeit. Kremmen, Germany 2005

▷ Geitmann Sven. Wasserstoff-Autos – Was uns in Zukunft bewegt. Hydrogeit. Kremmen, Germany 2006

▷ Grube Rüdiger and Evers Arno A. Neue Technologien im Flugzeugbau. Leuchtturm Verlag. Alsbach, Germany 1985

▷ Heinberg Richard. The Party's Over: Oil, War and the Fate of Industrial Societies. Clairview Books, East Sussex, UK 2003

▷ Heinberg Richard. Peak Everything: Waking Up to the Century of Declines. New Society Publishers. Gabriola Island, Canada 2007

▷ Heuck Klaus, Dettmann Klaus-Dieter and Schulz Detlef. Elektrische Energieversorgung: Erzeugung, Übertragung und Verteilung elektrischer Energie für Studium und Praxis. Vieweg & Sohn Verlag. Wiesbaden, Germany 2007

▷ Hoffman Peter and Harkin Tom. Tomorrow's Energy: Hydrogen, Fuel Cells, and the Prospects for a Cleaner Planet. Mit Press. Cambridge, USA 2002

▷ Holland Geoffrey and Provenzano James J. The Hydrogen Age: Empowering a Clean-Energy Future. Gibbs Smith Pub. Layton, USA 2007

▷ Höller Stefan, Küter Uwe and Voigt Cornelia. Brennstoffzellen im Unterricht: Grundlagen, Experimente, Arbeitsblätter. Hydrogeit. Kremmen, Germany 2008

▷ International Energy Agency. Key World Energy Statistics 2009. Paris, France 2009

▷ International Energy Agency. World Energy Outlook 2009. Paris, France 2009

▷ International Organization of Motor Vehicle Manufacturers (OICA). World Motor vehicle production bycountry and type 2007 – 2008. Paris, France 2009

Oberboezberg, Switzerland 1987

▷ Kemfert Claudia.
Jetzt die Krise nutzen. Murmann Verlag GmbH. Hamburg, Germany 2009

▷ Kratz Sabine.
Energie der Zukunft: Bausteine einer nachhaltigen Energieversorgung. Metropolis. Marburg, Germany 2007

▷ Lehmann, Jochen and Luschtinetz, Thomas. 15. Symposium:
Nutzung Regenerativer Energiequellen und Wasserstofftechnik, Proceedings. Fachhochschule Stralsund. Stralsund, Germany 2008

▷ Meadows Donella H., Meadows Dennis and Randers Jorgen.
The Limits to Growth: The 30-Year Update. Chelsea Green Pub Co. Vermont, USA 2004

▷ Merriden Trevor.
Business the Nokia Way. Secrets of the Worlds Fastest Moving Company. Capstone Publishing Limited, Oxford, UK 2001

▷ Minchener Andrew.
Future Coal Supply Prospects. IEA Clean Coal Centre. London, UK 2009

▷ Mouchot Augustin B.
Solar heat and its industrial application. reprinted in 1987 from the edition of 1879. Olynthus Verlag.

▷ NREL.
Technology Brief: Analysis of Current-Day Commercial Electrolyzers. CO NREL/FS-560-36705. Golden, USA 09/2004

▷ OECD / IEA.
World Energy Outlook 2009. International Energy Agency. Paris, France 2009

▷ Quaschning Volker.
Erneuerbare Energien und Klimaschutz: Hintergründe - Techniken - Anlagenplanung – Wirtschaftlichkeit. Carl Hanser Verlag. Munich, Germany 2008

▷ REN21.
Renewables Global Status Report: 2009 Update. Paris, France 2009

▷ Rifkin Jeremy.
The Hydrogen Economy: The Creation of the World-Wide Energy Web and the Redistribution of Power on Earth. Blackwell Publishers. Malden, USA 2002

▷ Romm Joseph J.
The Hype about Hydrogen: Fact and Fiction in the Race to Save the Climate. Island Press. Washington, USA 2005

▷ Rühle Alf-Sibrand and Geitmann Sven.
Wasserstoff und Wirtschaft – Investieren in eine saubere Zukunft. Hydrogeit. Kremmen, Germany 2005

▷ Schewe Phillip F. The Grid:
A Journey Through the Heart of Our Electrified World. Joseph Henry Press. Washington, USA, 2007

▷ Schlabbach Jürgen:
Elektroenergieversorgung: Betriebsmittel, Netze, Kennzahlen und Auswirkungen der elektrischen Energieversorgung. Mit CD-ROM. Vde Verlag Gmbh. Berlin / Offenbach, Germany 2003

▷ Scott David Sanborn.
Smelling Land: The Hydrogen Defense Against Climate Catastrophe. Canadian Hydrogen Association. Vancouver, Canada 2007

▷ Sperling Daniel and Cannon James S.
The Hydrogen Energy Transition: Cutting Carbon from Transportation. Elsevier Academic Pr Inc. San Diego, USA 2004

▷ Steinhilper Rolf.
Produktrecycling. Vielfachnutzen durch Mehrfachnutzung. Fraunhofer IRB Verlag. Stuttgart, Germany 1999

▷ Tetzlaff Karl-Heinz.
Wasserstoff für alle: Wie wir der Öl-Klima- und Kostenfalle entkommen. Books on Demand.

Norderstedt, Germany 2008

▷ THEME Conference Committee.
Conference Proceedings: The Hydrogen Economy Miami Energy (THEME) Conference. The University of Miami. Coral Gables, USA 1974

▷ Verband der Netzbetreiber (VDN).
Deutsches Höchstspannungsnetz.
Berlin, Germany 2006

▷ Weber Rudolf.
Der sauberste Brennstoff. Der Weg zur Wasserstoff-Wirtschaft. Olynthus. Oberboezberg, Switzerland 1988

▷ Wilson John, Wilson William and Wilson James M. William Robert Grove:
The Lawyer Who Invented the Fuel Cell, Metolius Ltd, Hereford, UK 2007

▷ Winter Carl-Jochen.
On Energies-of- Change. The Hydrogen Solution. Policy, Business, and Technology Decisions Ahead. Gerling Akademie Verlag. Munich, Germany 2000

▷ Winter Carl-Jochen and Joachim Nitsch.
Hydrogen as an Energy Carrier.
Technologies, Systems, Economy.
Springer Verlag.
Berlin / Heidelberg, Germany 1988

Websites

▷ American Recovery and Reinvestment Act: **http://www.recovery.gov**
▷ Apple Inc.: **http://www.apple.com**
▷ Arno A. Evers: **http://www.hydrogenambassadors.com**
▷ Boeing Corp.: **http://www.boeing.com**
▷ Business Week: **http://www.businessweek.com**
▷ Cameco Inc.: **http://www.cameco.com**
▷ Consolidated Edison, Inc. (Con Edison): **http://www.coned.com**
▷ ENERGON Carl-Jochen Winter GmbH: **http://www.itshytime.de/**
▷ Energy Bulletin: **http://www.energybulletin.net**
▷ European Commission: **http://ec.europa.eu**
▷ European Hydrogen Association (EHA): **http://www.h2euro.org**
▷ Franz und Bigi Alt: **http://www.sonnenseite.com**
▷ Gartner, Inc.: **http://www.gartner.com**
▷ German Aerospace Center (DLR): **www.dlr.de/en/**
▷ Group Exhibit H_2/FC: **http://www.h2fc-fair.com**
▷ IEA Clean Coal Centre: **http://www.iea-coal.org.uk**
▷ Inwent - Internationale Weiterbildung und Entwicklung gGmbH: **http://www.inwent.org**
▷ Initiative-Brennstoffzelle: **http://www.initiative-brennstoffzelle.de**
▷ Nokia Corp.: **http://www.nokia.com**
▷ Solar Millennium AG: **http://www.solarmillennium.de**
▷ Tata Motors Limited: **http://www.tatamotors.com/**
▷ Tesla Motors, Inc: **http://www.teslamotors.com/**
▷ The International Air Transport Association (IATA): **http://www.iata.org**
▷ The National: **http://www.thenational.ae**
▷ Tokyo Gas Co., Ltd.: **http://www.tokyo-gas.co.jp**
▷ U.S. Department of Energy: **http://www.eere.energy.gov/**
▷ White House : **http://www.whitehouse.gov**
▷ William J. Clinton Foundation: **http://www.clintonfoundation.org/**
▷ World Nuclear News: **http://www.world-nuclear-news.org**

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First, I would like to thank the "inner circle" who has actively worked on this book. That is *Sven Geitman*, whose idea it was to write it, in December 2009. I have known Sven for many years, and we first met when he was an employee at the German Institute for Material Testing (BAM) in Berlin. Later, after he founded his own publishing company, we have met on various occasions. All of which had, as you may have guessed, something to do with hydrogen and fuel cells. Thank you, Sven, for motivating us to write this book. It was worth the effort, at least from my perspective!

Frau Daniela Peschka must be thanked very much. She came into my office in Starnberg as an intern in January 2001, originally for three month, but stayed with us ever since. I am still not quite sure, if this speaks more for her or more for us ... Thank you, Daniela, for giving so much motivation and for also taking initiative at difficult moments, when we had no idea how to proceed, let alone write this book.

Thomas Schirmaier, our graphic designer has also been working for me for many years. Based in Munich, he was the "visual eye" of the Group Exhibit Hydrogen and Fuel Cells at the annual HANNOVER FAIR until its handover to the Deutsche Messe AG in 2007. I was always surprised when Thomas would come out with a new draft, be it for a visitor's brochure, the signature of the exhibitor's booths, or the forum program. Thomas has also worked hard on the more than 300 information graphics that we have released since 2003 on our website, on my presentations on hydrogen and fuel cells at conferences, and also on our numerous posters we have presented worldwide. Watch out, there is much more to come.

Ulrich Felger has been our webmaster from the beginning. He is now referred to as the IT Manager. Both job titles hardly capture how much Uli is actually doing. Firstly he has to cope (patiently) with my many spontaneous ideas, popping up during the day and which I want to have realized within, let us say, the next ten minutes. Uli sometimes has them ready in five minutes. He organizes our web page of over 7,000 active pages, each with their own URL, around 12,000 photos, which we have actually never counted. We have a vivid background information section, also regularly updated. During the HANNOVER FAIRs, Uli is in charge of a team of up to 30 people: photographers, picture editors, copy writers, movie teams and so on. They all are unbelievable busy to fill in the pages of our live Internet documentation at the fair. In good times, they finished more than 500 pages in the one week of the fair. All of them are still online, as you can see for yourself.

Erik Wilhelm helped us a lot, too. Erik heard about this book in January 2010. I asked him to "browse over the text", which he eagerly did. However, not only with his corrections, but also with his comments he helped me a lot considering what I actually really wanted to express. So the version that you are reading has been positively influenced by Erik. I met Erik first at the HANNOVER FAIR 2006, when he was one out of 32 hydrogen ambassadors in the Team Canada II, presenting a Fuel Cell Diver Propulsion vehicle. Now Erik is PhD Candidate at ETH Zürich, Switzerland. Additionally, Erik is also the Technology Director of his own company VirVe, which aims to support the transition to clean and fuel efficient transportation

technologies through intelligent analysis of the best available data and implementation of accurate vehicle simulation. He should do well.

The photos from *Wolfgang Steche* from VISUM, have given the book an additional kick, because they are always very on point. I have known Wolfgang since the 1970's, when I was press officer at the Hamburg Airbus plant of the former Messerschmitt-Boelkow-Blohm GmbH. Wolfgang was taking exceptional photos of our aircraft manufacturing sites, and, even more impressively, he also took good pictures of the management who are sometimes hard to capture in pictures. Wolfgang always kept in contact; he attended many of the HANNOVER FAIRs, where we then had the one or more cups of coffee together.

T. Nejat Verziroğlu, the co-founder (1975) and President of the International Association for Hydrogen Energy (IAHE) wrote our preface. He is by far the best person promoting hydrogen worldwide. Nejat had the foresight to initiate the very first international Hydrogen Conference: The Hydrogen Economy Miami Energy (THEME) Conference in March 1974. I have the proceedings of this No. 1 hydrogen conference in hand and can recommend the reading of this valuable material to everybody. Nejat is also the Founding Director of the Clean Energy Research Institute at the University of Miami, where I have visited him in 1999. We first met in 1996 at the 11th WHEC in Stuttgart, Germany. Nejat was also the keynote speaker at our international conference "Decentralized energy systems – a revolution in the energy market? Commercialization of Hydrogen Technology and Fuel Cells" at the HANNOVER FAIR in 2002. We have met many times in the following years, and I am looking forward to meeting him and his wife again at the 18th WHEC in Essen this year.

Special thanks goes to *the team* with whom I started the Group Exhibit Hydrogen and Fuel Cells at the HANNOVER FAIR back in 1995. The first on the payroll was *Ulli Walter*, who did marvelous moderations every year. The progress in his work was and is unbelievable! The same applies to *Tobias Renz*, who joined my company in 1996. In 2006 he took over the "regime" himself, organizing the Group Exhibit with his own vision. He could not have had better support from anyone besides *Megan E. McCool*. Megan, a remarkable young lady, started with me in 2005, and later continued with Tobias to become FAIR (which she already was). Also *Chupa Coules* left her footprints in our office. From 2003 through 2006 she was a great help in organizing the exhibition and everything that went along with it. Journalist *Werner Stuetzel* also falls in this category. When we met first, the battery of his recorder died, an incident which we still laugh about years later.

Without knowing that I would ever write a book, I have been influenced by a number of people both actively and passively. I am talking about: *Amory B. Lovins, Prof. Jochen Winter, Jeremy Rifkin, Peter Hoffmann, Karl-Heinz Tetzlaff* and *Ulf Bossel*. Amory, at the time Director of Research at the Rocky Mountain Institute, was invited by Deutsche Messe AG to be a keynote speaker at the Energy Summit "Winding down nuclear energy - where to begin?" at the HANNOVER FAIR 2000. He then took a rather comprehensive guided tour of our exhibitors, which were 33 at that time. Now we have over 140 exhibitors. In his work, *Amory B. Lovins* is known to be a strong advocate of the hydrogen economy, and has cooled down on this topic in recent years. I have shared many adventures with Jochen, such as the rather compressed journey through Argentina in 2004. Jochen was a speaker at our first Group Exhibit in 1995, thank you for that. I was pleasantly surprised to find out on-site that Jochen was also the co-founder of the Plataforma Solar de Almeria in Spain. *Jeremy Rifkin*, President of the Foundation on Economic Trends (FOET), USA, I met at

the 16th World Hydrogen Energy Conference (WHEC), 2006, in Lyon, France. Among others, he also wrote the book "The Hydrogen Economy" (2002). *Peter Hoffmann* is rather an "old hand" for hydrogen and fuel cells. He is founder, researcher, editor, and publisher of the renowned Hydrogen & Fuel Cell Letter, subtitled: Alternative Energy News, since 1986. I visited *Peter* and his *wife Sarah Briggs Hoffmann* twice in their nice house in Rhinecliff at the Hudson River, NY.

For Karl-Heinz's book "Wasserstoff fuer alle" (Hydrogen for Everybody) I wrote the preface. I support his idea to produce hydrogen out of renewable biomass. Ulf, the last in this list, is a renowned conference organizer, together with his family. His hydrogen and fuel cells conferences have a special charm, not only because of their location in Lucerne, on the Lake Vierwaldstäder See in Switzerland. Although he sometimes promotes the electricity system a little too much, he also only wants the best for the progress in our technology.

There are many other people to be mentioned, who indirectly supported the realization of the book. They are for me the hydrogen romantics to be mentioned and thanked: *Prof. Engin Ture* with his wife who I have met at various occasions. Then there is *Juan Carlos Bolcich*, president of the Argentine Hydrogen Association, who guided me around his country in 2004. I was delighted to have met *Frano Barbir, Prof. Giuseppe Spazzafumo, Prof. Andrew Dick* from Australia with his wife, *David Sanborn Scott* with wife and *Luigi Bonadio*, from Australia. Also with *Thorsteinn I. Sigfusson* and his wife from Iceland I had many fruitful discussions.

Next in line are the people from Deutsche Messe AG (DMAG) in Hannover, one of the largest fair organizers worldwide, provider of 32 exhibition halls "… able to host three Jumbo Jets each at a time …". It is hard to explain the sheer size of the fairground to potential exhibitors (especially for American ones). First I have to thank *Hubert H. Lange*. He was the one who discovered my ability to organize huge events, something I didn't know I could do, before. Next comes *Prof. Dr. Dr. h.c. Klaus E. Goehrmann*, former chairman of the board of DMAG. I also got along well with *Sepp D. Heckmann*, his successor. Thanks as well to *Martina Luebon* and *Ernst Runge* from the CeBIT Computer Fair team in Hannover, whom I meet first on Mai 18, 1990. *Arno Reich* has to be thanked as well as *Rene-Reza Mertens*, who not only helped me in finalizing my contract with Deutsche Messe AG in 2006. *Uwe Peters* from the purchasing department helped me in overcoming the administrative hurdles; we both speak the same language (Hamburger dialect). And, of course, *Dr. Wolfram v. Fritsch*, the CEO of Deutsche Messe AG, and *Oliver Freese* must be thanked. They always have oversight over all the basic elements of their huge fair events!

Together with *Wolfgang Pech*, I visited *Dr. Dipl.-Ing. Dr.-Ing. E.h. mult. Ludwig Boelkow* in 1994. We were both very impressed by the power of my former boss, the founder of the German Aircraft Industry. He was 82 years old at that time, explaining to us full of enthusiasm the advantages of a Hydrogen Society. The former press officer of *Dr. Boelkow* was *Eduard Roth*. He gave me the opportunity to come to Munich, the headquarter of MBB in 1985. I started there in Hamburg in 1970, together with a fellow-apprentice, who is now the CEO of Deutsche Bahn, *Dr. Ruediger Grube*. With Ruediger I have had some rather exciting years ever since. We edited our first book together in 1985 to help him with his PhD.

The Group Exhibit Hydrogen and Fuel Cells would be nothing without its exhibitors.

Here I would like to mention first *David Haberman* with *Nancy*, one of the first five US

exhibitors, with their former company DCH Technology in 2000. From David I received the Hydrogen Award for my livelong achievements of hydrogen energy in 2009. Our other first US exhibitor was *H Power Corporation*, represented from 2000 through 2002 in Hannover by *H. Frank Gibbard*, *Rene Dubois*, and *RJ Peters*. I visited them in 1999 at their headquarters in Belleville, NJ. RJ later joined us as moderator and team member on our public forum stage at the HANNOVER FAIR.

From the German exhibitors I have to mention first the *Fraunhofer Institute for Solar Energy Systems*, who are represented by *Dr. Christopher Hebling* and Dipl.-Ing. Ulf Groos. Representing thanks to *Werner Hoyer, Erich Gülzow, Dipl.- Ing. Josef Kallo, Dipl.-Ing. Andreas Brinner, Professor Dr. K. Andreas Friedrich* and *Dr. rer. nat. Christoph Richter*, who guided me through the Plataforma Solar de Almeria, all from the *Institute of Technical Thermodynamics at the German Aerospace Center (DLR)*. This institute from DLR is, in my opinion, the most advanced institute for H_2/FC research worldwide.

One of our most important exhibitors is the *Canadian/German Hydrogenics Corporation*. *Hugo Vandenborre*, who merged his Belgian company *Hydrogen Systems N.V. with Hydrogenics*, was with us as early as 1995. At that time, he was a speaker in the forum representing a two-person company. When asked, what he is doing, he said: "We are going to build electrolyzers. When they are ready, I will come back ..." That he did in 1998 as an exhibitor. *Mark Kammerer* and *Jane Dalziel* need to be mentioned, our later Hydrogenics' fair contacts for many years.

Norsk Hydro Electrolysers AS also belong in this group, after having exhibiting with us since 1996. Here *Andreas Cloumann* and *Hilde Henriksen Kaasa* come to my mind. *Dr. Vera Ingunn Moe* is one of the most remarkable women I have ever met. She impressed me every time we have met in different places around the world. Norsk Hydro Electrolysers AS has changed their name quite often, and occasionally we even had to update their signature at their booth during the fair. Many good suggestions came from many employees from the *Ballard* organization, both in Canada and Germany. Also from *Plug Power* we received a good number of requests, which we implemented piece by piece to complete at the fair our renowned "Full Service Package".

The next group includes further representatives from research institutions. *Dr. Manfred Wilms* from the *Technology Transfer Office of the Research Center Juelich (FZJ)* I met at HANNOVER FAIR 2000 for the first time. Manfred is one of the few who regularly visited our small Starnberg office to develop and discuss new features for the next year's event. I have often met *Dr.-Ing. Detlef Stolten* and *Dr. Robert Steinberger-Wilckens* from *FZJ* worldwide at different conferences

From *ZSW* many contacts come into my mind: *Dr. Juergen Garche* showed up at the HANNOVER FAIR 2001 for the first time. I remember quite well when we met at the 15th World Hydrogen Energy Conference (WHEC15) in Yokohama, Japan, when Essen received the WHEC 18 in 2010. With *Prof. Dr. Werner Tillmetz*, member of the ZSW board and *Klaus Steinhart*, Marketing and Sales, and his ZSW-team we found a good mutual understanding as comrades in arms.

Claude Jean from the *French Atomic Energy Commission (CEA)* was one of many exhibitors who I not only met during the HANNOVER FAIR, but also at many international conferences worldwide.

Thinking of our commercial exhibitors, we have to think of *MTU Onsite Energy GmbH Fuel Cell Systems* from Ottobrunn near Munich. With the former CEO *Michael Bode* I had plenty of common ground because we both came from the same "tribe" of the German aircraft industry. Thanks also to his staff that have supported us with their presence at the fair. It was a pleasure to host *Ceramic Fuel Cells* from Australia with Dr. Karl Foeger as the Chief Technology Officer of Austrian origin at our exhibition since their first appearance in 2004.

With the owners and operators of *h-tec, Wasserstoff-Energie-Systeme GmbH, Hydrogen Energy Systems, Uwe Kueter, Stefan Hoeller* and Marketing *Director Åke Johnsen*, a renowned German producer of education equipment, I developed an especially close relationship. Their story is hard to beat: Uwe and Stefan met at the second Group Exhibit at the HANNOVER FAIR 1996, shortly after they had finished their university studies. Later, they founded their company in Luebeck and joined us again in 1997, this time as a exhibitor! Well done, it is always interesting to observe their development from one fair to the next.

Nicole Seidl, the owner and operator of *QuinTech e.K.* earns my highest respect. Nicole has been exhibiting with us since 2001. At that time she was still exhibiting in the Research and Development Hall 18 at the HANNOVER FAIR. As early as that, she brought *Radha Jalan* from *ElectroChem, Inc.* based in Woburn, MA, USA with her. Radha is so dynamic that she is continuing to run the company which she took over from her early deceased husband. Even with only limited knowledge of the technology, she built up ElectroChem to reach new horizons very successfully. Thank you Radha for taking the lead!

Proton Motor Fuel Cell GmbH, formerly from Starnberg, our office town, and now based in Puchheim near Munich, provided me with the pleasure of my first bus ride in a hydrogen driven bus. Joining us in 1998 as an exhibitor, they also have developed well over the years. My thanks goes to *Dr. Joachim Kroemer*, Business Development, and his team, who always surprised us with new ideas at each successive HANNOVER FAIR.

Here I also have to thank *Norman Strate*, former CEO, and *Dr. Mohammad Enayetullah*, former Director of *Advanced Technology at Protonex Technology Corp.* based in Southborough, MA, USA , where we also met first. During HANNOVER FAIR 2004, both had been on stage at a forum interview, which I spontaneously gave to them for free on-site. We have been friends ever since.

My best wishes go to *Dr. David Edlund*, former CEO of *IdaTech, LLC* from Bend, Oregon, who was keynote speaker at our International Conference Energy Summit: "On the way to a Hydrogen Economy" during HANNOVER FAIR 2001, and who has also exhibited with us for a number of years. Thanks also go to *Mark-Uwe Oßwald*, Managing Director of *FutureE Fuel Cell Solutions GmbH*. He came to exhibit at HANNOVER FAIR in 2009 for the first time. I was delighted to see their approach, and had some

additional discussions with Uwe at the 2009 INTELEC in San Diego, CA, USA.

Frau Sabine Wichmann, the CEO of our booth-building company, and her team helped me out in many ways, not only on questions related to the fair. She also inspired us to develope our "Full Service Package". In a period of over 15 years, we have created an added value for our exhibitors and also for the visitors of the fair. This package is unmatched in fair or conference business I know of. I am proud of the fact that we have been able to hold this high standard for such a long time.

Indirectly I have also to thank *James F. Bell*, III, Professor of Astronomy from *Cornell University, NY, Astronomy Department's Center for Radiophysics and Space Research*, author of many books like: Postcards from Mars. James is the Payload Element Lead for the Pancam color cameras on the Mars Exploration Rovers Spirit and Opportunity. We met at an energy conference in December 2009. I was very impressed with his management skills and achievements. A very inspiring person!

Last but not least I also would like to thank my *mother*, at an age of 86 as we are working on this book. She indirectly has influenced me with the idea to store the sunlight in big bags in summer and use its contents in winter. Thank you, dear *Erika*. I wonder why we haven't done that!

Impressions from the Group Exhibit
Hydrogen + Fuel Cells
at the annual HANNOVER FAIR

Production
Reduced metal-oxide
Oxygen
Hydrogen
Water
Conclusion towards the Hydrogen Society
Direct Solar Hydrogen and Fuel Cells
Global applications of Personal Power Providers (3P+)
Your Personal Power Provider (3P+)

About the Author

Arno A. Evers started his career in 1965 with a British oil exploration company in the Middle East, later joining the German aircraft industry. Arno was involved from 1969 through 1985 in implementing the European Airbus Program, bringing their A300 – A380 series to the international market from their Hamburg plant. Arno's last position was Deputy Spokesman at the Munich-based Messerschmitt-Boelkow-Blohm GmbH (MBB, now part of Daimler AG) where he served 23 years. He then started his own company, Arno A. Evers FAIR-PR in 1990 in Munich, Germany with the goal of simplify trade fair participations for exhibitors. Subsequently, he organized several conferences and symposia on computer and communication technology, the environment, as well as on hydrogen and fuel cells technologies.

Arno founded the Group Exhibit Hydrogen + Fuel Cells at the HANNOVER FAIR in Germany in 1995 to serve as a bridge for moving this technology from laboratories to practical applications. He led the entire organization of the Group Exhibit which developed into Europe's largest industry and research gathering, while introducing and refining his full service package for exhibitors. In 2006 he transferred his ownership to the Deutsche Messe AG, who is the owner of the worldwide biggest fairground in Hannover, Germany.

From 2006 through 2010, he attended numerous H_2/FC conferences and trade shows worldwide to promote the Group Exhibit, as well as to provide unique internet documentation about the events and other informative areas on-site.

He has published more than 300 information graphics (Energy Images) and 50 newsletter contributions (Arno's Energy Ideas) on alternative energy, and now serves as a hydrogen ambassador not only as a speaker at conferences, but also as a lecturer at universities. Being the editor of the internet-portal www.hydrogenambassadors.com, Arno presents his long sought goal of a Hydrogen Society, and stimulates the integration of the direct solar hydrogen production as an essential part of the global hydrogen movement.