JPR-Focus No. 02/25

The newsletter of JPR Concepts & Innovation in the new format and still free of charge.
Published in three languages - German, French, and English - now 2 to 3 times a year.
Deepened, holistic viewpoints on current issues.
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Dear Readers

A warm welcome tot he second 2025 issue of the JPR-Focus.

Many publications state that hydrogen plays a central role in the energy transition. As a result, big plans are being made. The construction of a hydrogen network and the conversion of certain parts of the existing gas network should be started immediately.

Some people have now also understood that the energy sector is not the sole culprit when it comes to climate issues. A new term has been coined: the decarbonisation of the economy. This does not mean abandoning carbon altogether, but rather reducing or avoiding CO2 emissions and moving away from fossil fuels such as coal, natural gas and petroleum. This choice of words does not necessarily help to clarify what is at stake. Hydrogen is also set to play a central role here.

Despite these promising prospects, the hydrogen sector does not appear to be making a breakthrough. Everything remains at the vision and virtual plan stage. There are a few success stories, but they do not prove the feasibility of the grand plans; rather, they highlight the constraints that apply.

The aim of this report is to shed light on the interrelationships so that the topic can be better understood and the potential of hydrogen adequately recognised.

I wish you an entertaining read.

Yours Jean-Pierre Rickli

Hydrogen
Can he really fulfil all expectations?

1. Introduction

Hydrogen has an important role to play in the energy transition and in decarbonising the economy. Many reports, company announcements and studies attempt to substantiate this statement. Seminars and conferences are held on this topic. Huge investments in suitable infrastructure are to be made by the state. The result is little more than hot air. Why?
I see primarily the following reasons for this:

- All visions of the future focus solely on final demand, usually expressed in kWh.
- Hydrogen production is considered a purely technological problem. Which processes? Which efficiency? Which transportation and storage possibilities?
- The important questions are not being asked. Who will fill the network? Where will this happen? How much is needed? Is the infrastructure for production even available? Additionally, the answers to these questions vary greatly from sector to sector.
- I see the final main reason simply in the old adage: the devil is in the details.

We will not discuss the first two reasons in detail here. In this context, I will only point out some of the consequences of this approach.

The central point of this report will be the analysis of the third reason and also of the possible lack of motivation to deal with the relevant issues, a fear of the devil. Answering such questions requires dealing with the details. This in turn requires a certain amount of knowledge, a willingness to go into depth and thus also to accept a certain effort.

2. The Hydrogen

Before we even discuss it in this report, we need to get to know the main player better. Do not worry, this is not going to be a chemistry lesson. The aim is to understand why it is considered to have such a potential and what technological challenges it poses.

2.1 What is so interesting about hydrogen?

In today's debate on the energy transition, it offers the following advantages

- It is abundant on Earth, namely in water.
- Its reaction with oxygen releases a lot of energy. We use this energy-rich combination to propel the rockets we launch into space.
- The end product of this reaction is water. Consequently, when we extract hydrogen from water, there is no loss of material and no harmful substances that we need to dispose of.
- While respecting some constraints, hydrogen can be transported and stored. That allows to decouple the consumption from the production.

When it comes to decarbonising the economy, it is not only important as an energy source, but can also be used as a raw material for creating substances. For example, fuels could be produced from hydrogen and CO2 recovered from the air. Other products are on the waiting list. Many such processes are already in the testing phase, but many others exist only as ideas on paper. How such processes might work is largely a matter for the future.

2.2 Special characteristics

As we have seen above, hydrogen is abundant, but it is bound to oxygen as water. To obtain hydrogen, this compound must be broken down, which requires a lot of energy.

Hydrogen reacts very violently with oxygen (oxyhydrogen gas). On the one hand, this is advantageous when used for heat generation. On the other hand, it poses a serious risk during storage and transport. Special precautions are essential.

The hydrogen atom is the smallest of all elements. This means that hydrogen has a very high diffusion capacity. Special materials are therefore required for storage and transport containers. The use of the existing gas network would therefore have to be thoroughly reviewed. Major and expensive adaptations are therefore entirely possible.

On this point, opinions diverge. Some plead in favour of building an entirely new network. On the other hand, they are some expertise reports demonstrating that utilising the existing gas network does not present great problems. Were laws of material physics newly invented? Are they special interests behind such statements? Were the necessary pre-conditions banned into the small-prints which nobody reads.?

2.3 His colours

Hydrogen is, of course, colourless and, as a gas, cannot be detected by the eye. Nevertheless, publications contain numerous references to green, grey, blue and other colours. This has nothing to do with hydrogen itself, but rather with its origin and the type of energy used to produce it. This colour coding is primarily a marketing ploy, some would say, with varying degrees of "greenwashing".

Here is an overview of the most common colours:

- Green
  It is the most promising colour of hydrogen. The electricity used for electrolysis was produced with wind or solar energy. This hydrogen is therefore considered climate-neutral. The major problem with this approach is the high demand for green electricity, which severely limits the alternative use of green electricity.
- Blue
  Hydrogen marked with this colour is obtained from steam reforming. The energy source required for this is natural gas, oil or coal. The CO2 produced during this process is captured and stored underground. This means that this hydrogen is also considered climate-neutral. CO2 capture and storage are proven technologies, but they are energy-intensive. As they use green power, they may limit other uses. In addition, the requirements for storage sites are quite high, which greatly reduces the number of suitable locations.

- Grey
  Hydrogen with this colour designation is the opposite of green hydrogen. The electricity for the electrolysis production of this hydrogen comes from fossil fuel power plants. It is therefore not considered as climate neutral.
- Turquoise
  This hydrogen is obtained from a thermal process – methane pyrolysis – in which methane or natural gas is split into hydrogen and solid carbon. Provided that the carbon is permanently bound, this process is also CO2-neutral. Of course, all plant components must be operated with renewable energies.
  Since the electricity required for operation is significantly lower than in the other previous variants, turquoise hydrogen is often presented as a transition to green hydrogen.
- Red, violet, pink
  All these colours are used to label hydrogen produced by electrolysis powered by electricity from nuclear power plants. Since this electricity is produced with almost no CO2 emissions, these colours are climate-friendly. Other aspects, such as uranium mining, the safety of such plants and the disposal of radioactive waste, are topics dealt in other discussions.
  For many, these discussions are unnecessary, as this approach is primarily intended for existing plants. If these plants are allowed to produce electricity for as long as possible, the overall ecological balance can only improve. This also means that hydrogen production can be ramped up independently of the expansion of solar energy.
- Orange
  With this colour, hydrogen is usually also produced via electrolysis. However, the electricity required for this is generated in biogas power plants and waste incineration plants. This means that this hydrogen is not entirely climate-neutral, but it can improve the ecological balance of other consumption sectors.
  Biogas and waste incineration plants are local facilities with limited reach. This means that orange hydrogen also has a local character.
- Yellow
  The hydrogen in this colour is also obtained through electrolysis. The electricity for this comes from the German electricity mix, which means it includes electricity from both renewable and fossil fuel sources. This hydrogen is also not considered climate-neutral, but it is less harmful than grey hydrogen.
- White
  White hydrogen is hydrogen that occurs naturally. It is found in natural deposits in deep rock layers. This hydrogen could be extracted using methods such as fracking. This means that this hydrogen is only climate-neutral to a limited extent. Furthermore, it is not sustainable, as these deposits are not renewable.

In addition to this already very colourful palette of hydrogen types, there are two more colours worth mentioning. They play a minor role and were introduced primarily because of the different subsidies and approval deadlines.

- Black
  This label is used for hydrogen where the electricity for electrolysis comes from coal-fired power plants and is therefore not climate-neutral.

- Brown
  This colour is used for hydrogen that is powered by lignite-fired power plants and is therefore not climate-neutral.

This colourful list highlights an important part of the problem surrounding climate-neutral, green and environmentally friendly hydrogen: obtaining enough electrical energy for hydrogen production.

The path to 'green hydrogen' is directly linked to the generation of green electricity from renewable energy sources. Today, we are not yet in a position to meet our basic electricity needs for lighting, household appliances, drives and for communication with renewable energies. This formulation is actually very positive. Some say it is 'a long way off' or talk of the illusion that such a thing is even possible. Where, then, is the energy needed for the production of the hydrogen necessary to fill a pipeline network such as today's gas network supposed to come from?

This also shows us that, for some time to come, further handling for its transport and storage will continue to give hydrogen a more or less strong grey hue, except for black and brown. It is also clear that the assessment based on climate neutrality is not adequate.

3. What are the envisioned potential applications for hydrogen?

3.1 Power and heat supply

When the energy transition was announced, everyone thought that hydrogen would be the energy source of the future. Grand visions were conceived at the planning tables. Everything seemed wonderful. The first power plant projects were launched, and soon the question arose as to where the large quantities of hydrogen would come from.

Green hydrogen was a distant prospect. Different combinations were studied, hence the variety of colours. However, even a timely expansion of electrolysis capacity was out of the question. These power plant projects were simply put on hold.

What remains are projects in remote locations, such as islands. These places usually have plenty of wind and, in southern locations, sufficient solar insolation. These are good conditions for green hydrogen.

The distances there are also manageable. In addition, energy demand is limited to private households, local businesses and craft enterprises. This means that a balance between energy supply and demand can also be established. Surpluses are stored in batteries or hydrogen storage facilities. This can also be used to provide energy for local transport – with batteries or fuel cells.

3.2 Transportation of goods and persons

Then we come to a complex topic, or rather three complex topics: transport of goods and persons on land, water and in air. Since the issues involved are very different, we need to look at them separately.

The focus of applications and projects involving hydrogen is based on fuel cell technology as a general principle.

An alternative would be to use hydrogen to produce fuels such as ethanol or methanol. The carbon component would then come from plants that extract CO2 from the air. However, due to the high energy consumption – energy for electrolysis, energy for extracting CO2 from the air, energy for the fuel production process – such a solution is still a long way off.

3.2.1 Land Transportation

The smaller power rating of the units for the transportation of goods and persons on roads has enabled the development of various solutions.

According to the prevailing business understanding at the time, the greatest market potential was seen in automotive drives – large numbers, lower technical risk, lower financial risk, large market reach. Many car manufacturers developed corresponding concepts and launched new models on the market on a trial basis to allow the technology to mature.

Disillusionment came soon. Where would the hydrogen for widespread use come from? Apart from the test fields, there was nothing. No one had bothered to look into it. There was no money for widespread expansion. Everything was too uncertain and too expensive.

It was also another sobering moment for everyone who believed that multiple energy conversions – from renewable energy, wind or solar, to electricity, from electricity to hydrogen, from hydrogen to electricity, from electricity to mechanical energy – are equivalent or even better than the two conversions – chemical energy to heat and heat to mechanical energy – performed by a combustion engine.

One alternative was to offer a comprehensive solution, i.e. electricity production via solar panels, hydrogen production via electrolysis, hydrogen storage and a vehicle fleet with adequate propulsion systems, and, if necessary, conversion of existing vehicles to fuel cells.

Such solutions have been successfully implemented by various transport companies (public transport buses) and local goods distribution. Until now, these solutions have remained niche applications due to cost considerations.

Tests were carried out on the railways with converted diesel locomotives. The feasibility was demonstrated. However, these tests were not pursued further for cost reasons. Due to the high-power requirements, it was not easy to implement a power generation unit with fuel cells for wider application.

3.2.2 Water Transportation

Theoretically, there are many possibilities both for goods and persons transportation, at least from the perspective of the drive unit alone. However, when hydrogen supply, ease of maintenance, the required power output and operation are taken into account, the picture changes. The variety of combinations means that only niche solutions are possible in practice.

A few examples:

- Removable outboard solutions for small recreational boats that are used sporadically cannot simply be replaced by fuel cells at present. Small boats that are in regular use – fishing boats on lakes – could possibly be retrofitted with a permanently installed solution. However, this would have to take up very little space so as not to interfere with fishing operations. An easily removable electric motor with a battery pack could be a solution.
- For medium-sized recreational boats with permanently installed propulsion systems, conversion to fuel cells would be conceivable. However, operational readiness would have to be guaranteed even during longer periods of inactivity. They would have to be low-maintenance and not require any special expertise. Even more conceivable would be their use in small boats for passenger transport on small lakes.
- For larger ships, up to the very large ones, maintenance issues are somewhat less of a problem, as maintenance personnel is available. However, the problems shift towards power size – high power fuel cells are hardly available – and, above all, towards the supply of very large quantities of green hydrogen.

3.2.3 Air Transportation

Many see hydrogen as the fuel of the future for aircraft, primarily for generating electricity for the electric motors of propeller drives. Direct use in the engines would also be conceivable, but this is clearly a secondary consideration.

For those in favour of this solution, it is very clean, even emission-free, i.e. without CO2. The product of the exothermic chemical reaction between oxygen and hydrogen is pure water. This can be released into the air without hesitation. Unfortunately, for me and a growing number of people, this is only supposedly the case, because water in the upper layers of the atmosphere not only forms condensation trails, but also clouds. There, water vapour is a powerful greenhouse gas. Even AI cannot combat or prevent this.

This example perhaps explains why I am very cautious about focusing solely on CO2 in the objectives of CO2-free, CO2-neutral and the like. In the above case, this would greatly worsen the situation instead of improving it.

3.3 Production of chemical substances

We are hearing and reading more and more in the media about the decarbonisation of the economy. This does not mean carbon-free. That would be unrealistic and contrary to many natural processes. No, it simply means without the use of fossil fuels such as coal, lignite, oil and natural gas. The second goal would be zero CO2 emissions or at least a balanced CO2 footprint, i.e. climate neutrality.

A very honourable goal. Important industries such as steel production, cement production and, above all, the chemical industry with its wide range of products are affected.

However, one important fact is being forgotten or overlooked: coal, natural gas and oil are only partly energy sources for these industries. To a large extent, they are also suppliers of raw materials that are used in chemical processes. If we want to leave them out of the equation, we need to find a substitute for every C or H atom elsewhere in the production process. The carbon atom is then supplied from CO2 extracted from the air, and the hydrogen atom is made available today through electrolysis. Both processes require a large amount of energy.

Moreover, many compounds found in oil, in natural gas or in coal must then be synthesised. The development of these processes will need some time. We will then know how much energy will be needed for them.

4. A few helpful numbers

4.1 General considerations

In the above explanations, we have seen that although hydrogen is abundant on Earth, it only becomes available for other uses after a certain amount of energy has been expended. The availability of green electricity is crucial for the production of green hydrogen if we insist that CO2 emissions are the cause of climate change. Anything else is merely window dressing.

We have to understand that the CO2-content in the air is on the one hand an important indicator and on the other hand a balance number. The balance is the result between what is emitted and what is retained or separated. It is then clear, that behind any measure aiming to reduce the CO2-output, a grey CO2 is hidden.

This is the CO2 generated by all activities related to building a plant - mining raw materials, their treatment, fabrication of components, construction, maintenance, decommissioning and disposal of the old parts, etc. Especially of interest is any transport activity. Each transport is basically unsustainable and gives a grey note to any product, independently on how "green" it is. This this note becomes stronger with the distance covered.

Also to be considered is any loss of CO2 retaining capacity of soils and water basins due to damages and pollution from the above activities.

The use of other colours of hydrogen is then possible or allowed.

I have pointed out on several occasions that solutions have not been pursued due to the unsecured supply of green hydrogen. There seems to be a hidden problem with quantities behind this. How big is it, at least approximately? Perhaps this is the hidden reason for the slow progress?

We have also seen that natural gas, oil and coal are suppliers of raw materials. If we move away from them, we will have to replace these raw materials. What this means in terms of quantity is hardly covered in today's flow of information. A rough estimate is sorely needed.

In order to obtain a more accurate estimate, we need various figures, which are shown in the following sections.

4.2 How much electricity is needed to produce hydrogen?

A brief review of the electrolysis market indicates that, on average, 4.5 to 6.3 kWh are required to produce 1 Nm3 (standard cubic metre) of hydrogen. The range is due to the varying conditions of the different processes and the size of the plants. For our estimates, we will use a value of 5 kWh per Nm3 as a basis.

I can already hear the indignant voices of specialists in this field telling me that major advances in efficiency are still to be expected. That is correct, and I have no problem with that. All I can say in response is that such advances only affect the first few digits of a number, not the number of zeros behind them.

To convert the energy requirement in relation to weight, it is important to note that the weight of 1 Nm3 of hydrogen is 0.0899 kg. This means that 55.62 kWh are required to produce 1 kg of hydrogen.

4.3 How much hydrogen does a fuel cell need to generate electricity?

We have seen that hydrogen is used as an energy source for power generation in many applications. In most cases, this is done using a fuel cell.

Here, too, there is a wide range of efficiency levels for the plant. This is a result of the different boundary conditions of the various processes and the size of the plants. The above comment on the still existing potential for improvement also applies here. We aim to estimate the order of magnitude rather than determine an exact value.

The electrical efficiency ranges from 35–40% to 60–70%. These values appear to be the typical efficiencies of the cells. The values for the assembly may be significantly lower. The literature cites a value of 50% as good. We will use that.

Since we primarily want to know how much electricity can be produced from one kilogram of hydrogen, we need to know which reference – low or high heating value – was used to calculate these efficiencies. There is a general lack of clear information on this point. The high heating value was most likely used. For hydrogen, this is 33.3 kWh/kg or 3.0 kWh/Nm3 or 120 MJ/kg.

For comparison, the lower heating value of hydrogen is 39.4 kWh/kg.

To produce 1 kWh of electricity, we therefore need an energy input of 1/0.5 = 2 kWh in the form of hydrogen, i.e. 0.06 kg of hydrogen.

4.4 How much water is needed to produce hydrogen?

Water is needed for electrolysis to make hydrogen from sources other than fossil fuels. But this water has to be of a specific quality or purity. Drinking water quality is the lowest level these days. Some electrolysis processes need better quality water to get higher efficiency.

It is therefore important to know how much water is actually necessary.
We determine this using the atomic weight of both components of water. The atomic weight of hydrogen is 1.00784 and that of oxygen is 15.999. Thus, the molecular weight of water, consisting of two hydrogen atoms and one oxygen atom, is 18.01468.

From these values, it can be deduced that the hydrogen content corresponds to 11.19% of the water weight. This means that 1/11.19% = 8.937 kg of water is required to produce 1 kg of hydrogen.

4.5 How much hydrogen is needed to replace fossil fuels?

Hydrogen is intended to replace fossil energy vectors and suppliers of raw materials, i.e. all types of coal, natural gas and crude oil. Since it does not occur naturally and cannot be extracted in a renewable manner, it must be produced from water. This is only possible with a certain amount of energy input. Today, the usual process for this is electrolysis.

It is therefore important to know what quantities of hydrogen can be expected globally or in individual cases. This makes it possible to estimate the corresponding energy requirements, i.e. the electricity requirements.

When it comes to applications in the pure energy sector, either the low or the high heating value is used. The low heating value is more commonly used in the power sector, while the high heating value applies in the heating one. Their use is more a matter of agreement and, as the values differ, it should be clearly stated which value applies.

However, if one looks at the standard documentation, especially the statistics, including the highly official ones, there is little evidence of this. Nor is there any mention of the different quality of energy respectively its potential to be converted into other forms of energy. There, one kilowatt is considered as one kilowatt, independently whether it is power or lukewarm water. It is possible to produce lukewarm water with power with a good efficiency, the contrary is not that easy. Nevertheless, the classification according to the application provides an indirect indication of this.

For our comparisons, we will use the high heating value for heating applications and for fuel cells. For power applications – drives, power plants, etc. – we will use the low heating value. The following tables show the low and the high heating values of a few typical fuels and propellants.

Matter	**Hydrogen**	**Methane**	**Methanol**	**Coal**	**Heating oil/Diesel**
Heating value high(MJ/kg)	120	50	19.9	25 – 32.7	43

Table 1: Heating values high

Matter	**Hydrogen**	**Methane**	**Methanol**	**Kerosine**	**Petrol**	**Diesel**
Heating value low (MJ/kg)	143	55.5	22.7	43	47	45.4

Table 2: Heating values low

It should be noted that some products, such as kerosene, diesel or coal, are mixtures of different products. This means that different values may apply in specific cases. The values listed here correspond to the most commonly encountered specifications.

4.6 How much hydrogen is needed to produce a substance?

Where hydrogen is the supplier of material for the formation of new substances, the required quantity is determined using the atomic or molecular weight in a similar way to that described in section 4.3.

This method can be used to estimate the quantity of any substance present in the new molecule.

First, the molecular weight of the final molecule is determined. Then the total weight of the hydrogen atoms. This allows us to calculate their proportion of the molecular weight and the corresponding hydrogen weight per kilogram of the final product.

It should be noted that this only refers to the hydrogen required for the formation of the molecule. The energy required for the provision of other substances, synthesis and production is not included here.

5. What are the quantities involved? – A few examples

For many, our future will be characterised by hydrogen as an energy vector. We now want to see what that would mean. The official figures from the Swiss Federal Office of Energy (BfE, Swiss Energy Statistics 2024) were used as a basis.

5.1 Replacing non-renewable electricity consumption

Let's look at electricity first. In 2024, we consumed 57'512 GWh. Of this, 22'983 GWh were produced by nuclear power plants, 1'433 GWh by thermal power plants using non-renewable energy sources, and 7'204 GWh from various renewable energy sources. The rest came from hydroelectric power plants.

This means that 24'416 GWh would still be produced from non-renewable sources. However, we can assume that the other renewable sources still have potential for expansion and could roughly double their production. This would leave 17'000 GWh of electricity which could be supplied with the help of hydrogen.

We have seen that 0.06 kg of hydrogen is needed to produce 1 kWh of electricity. To produce 17'000 GWh of electricity, 17'000'000'000 kWh x 0.06 kg = 1'020'000'000 kg or 1'020'000 tonnes of hydrogen are therefore required.

Since hydrogen is not readily available but must be produced using electricity via electrolysis, 1'020'000'000 kg x 55.62 kWh/kg = 56'732'400'000 kWh of green electricity must be provided for this purpose.

5.2 Covering the winter electricity gap

First, we have the problem of quantifying this gap. On the one hand, because predicting the future is always an uncertain undertaking and, on the other hand, because this figure is politically very sensitive.

According to the BfE's 'Energy Perspectives 2050+ – Excursus Winter Electricity (2021)', the electricity import surplus in winter can be used as a measure of this. From this, it can be concluded that it was reasonable in these years to expect an underproduction of domestic electricity amounting to 6 TWh in order to ensure a secure supply.

Since the Mühleberg nuclear power plant has now been shut down and electricity consumption has increased, this shortfall in domestic electricity supply is likely to be even higher. The figure of 10 TWh sometimes cited is probably not entirely incorrect, but it will only be reached in a few years' time. To enable a direct comparison with current consumption figures, we estimate this gap to be 7 TWh today.

We have two options here. The first is to store the hydrogen and use it in winter. The corresponding electricity demand can be determined as before. Using a 3-set, we can easily arrive at the corresponding figure: 7/17 = x/56.732. The required amount of electricity is then x = 23.360 TWh.

The other option is to store the energy in another substance such as methane or methanol. Although this solution has disadvantages in terms of energy, it offers major advantages in terms of transport, storage, distribution and handling.

Supplying 7 TWh of electricity in winter using methane via fuel cells requires an energy input of 7 TWh x 1/0.5 = 14 TWh of energy. Providing this via methane with a high calorific value of 13.89 kWh/kg corresponds to supplying 1'007'919 tonnes of methane.

The chemical formula for methane is CH_4. This means that its molecular weight is 1 x 12.011 plus 4 x 1.00784 = 16.0424. The weight of the hydrogen component is therefore 25.13%. This means that 0.2513 kg of hydrogen is required to produce 1 kg of methane. To supply 1'007'919'000 kg of methane, 253'290'040 kg of hydrogen must be produced. Its production then requires 253'290'040 kg x 55.62 kWh/kg = 14'087'992'000 kWh or 14.087 TWh.

This does not take into account the energy required for the provision of carbon and for synthesis.

5.3 Replacing diesel fuel

In order to achieve the goal of climate neutrality or decarbonisation, the 2'455'000 tonnes of diesel oil consumed each year would have to be replaced. A similar procedure would have to be followed for the 2'050'000 tonnes of petrol or the 1'799'000 tonnes of aviation fuel.

Here, too, the same two options are available in principle as for bridging the winter gap. Direct replacement via a hydrogen-powered drive or indirect replacement via an intermediate fuel that is compatible with today's technology, such as methane.

For simplicity's sake, we assume that the conversion efficiencies of the drives are not identical, but are very similar to the ones of diesel drives. Ultimately, it is primarily a question of order of magnitude. We can therefore determine the quantity of hydrogen and of methane required based on the low and high heating values.

Replacing 2'455'000 tonnes of diesel oil with a high heating value of 11.94 kWh/kg with hydrogen requires 880'261 tonnes of hydrogen. The production of this hydrogen then requires 880'261'000 x 55.62 = 48'960'117'300 kWh or 48.96 TWh.

To calculate the replacement of this amount of diesel oil with methane in the engines, the lower heating values must be used. Replacing 2'455'000 tonnes of diesel oil with a low heating value of 12.61 kWh/kg with methane with a low heating value of 15.42 kWh/kg requires the provision of 2'007'623 tonnes of methane.

As we saw above, 0.2513 kg of hydrogen is needed to produce 1 kg of methane. To produce the required amount of methane (2'007'623 tonnes), 507'928.7 tonnes of hydrogen are therefore needed. Producing this amount of hydrogen requires 28'250'993'000 kWh or 28.25 TWh.

5.4 Hydrogen for the synthesis of many substances

As already mentioned, petroleum, natural gas and coal are also sources of raw materials for industry, especially the chemical industry. Petroleum in particular consists of a mixture of many components. Using suitable processes, these components are separated and used as products or basis materials for the formation of new compounds.

If we want to dispense with petroleum, we must either give up these chemical compounds or develop new synthesis processes and provide the basic materials such as hydrogen and carbon. Hydrogen and oxygen could be made available through electrolysis.

We can estimate what this means by looking at a product that is very well known in our society but not particularly important in chemistry: PET.

Approximately 5 million tonnes of PET are produced in the EU each year. Its basic chemical formula is $C10H8O4$ and it has a molecular weight of 192.17. The eight hydrogen atoms thus make up 4.19% of the molecular weight. This means that 209'500 tonnes of hydrogen must be provided for the aforementioned production of 5 million tonnes. Producing this amount via electrolysis would consume approximately 11.65 TWh.

The oxygen could come from water electrolysis. The energy required for the provision of carbon – separation of $CO2$ from the air, splitting of $CO2$ – and for the synthesis process would also have to be added.

We can apply such considerations to virtually any product.

6. Conclusions

The figures from these examples actually show where the core of the problem lies. It is not a question of technology or efficiency. It is a problem of quantity. It is also a sociological and social problem. Of course, this problem is not unique to Switzerland. It is a problem faced by virtually every country, albeit to varying degrees.

Replacing just under 30% of our electricity consumption with 'green hydrogen' requires the additional use of practically our entire annual electricity consumption. This gives an indication of how much we are overusing our natural resources.

The so-called winter electricity gap results from the difference between production capacity and electricity consumption. Today, this difference is primarily due to higher consumption in winter. To a much lesser extent, it is also caused by seasonally lower production capacity. Closing this gap with hydrogen as an energy source would require to produce an additional 40% of today's electricity consumption from renewable sources.

As said, this additional production is to be carried out using renewable energies. This will clearly increase the seasonal difference. As a result, the additional electricity required for the seasonal shift could well be in the same order of magnitude as current consumption. Isn't this also a sign that we should return to a more natural rhythm of life?

So far, we have only considered electricity consumption. What about transportation of goods and persons?

Hardly any better. To replace diesel, we need an additional amount of electricity to produce the necessary hydrogen, which is about half of today's total consumption. Then we have petrol and aviation fuels, both of which are roughly the same order of magnitude.
Added to this, in similar quantities, is the amount of heating oil used for heat production.
That means twice today's electricity consumption in total for replacing the fuels.

Therefore, if we want to meet our energy needs in a 'green' way, we would need, roughly speaking, additional 'green' electricity production capacity to generate the approximately 200 TWh required to produce the necessary hydrogen. Some people have recognised this gap, at least in part, and have attempted to fill it with alternative supplies. Hence the many hydrogen colours.

In order to decarbonise the economy, hydrogen would also have to be produced in order to manufacture the substances and materials that are no longer to be obtained from petroleum. The energy required to produce the hydrogen needed for this purpose is also in the TWh range for most products. Note: 1 TWh (terawatt hour) = 1,000,000,000 kWh.

How can this enormous energy demand be met? Which energy sources can be tapped? Where are they located?

It is not enough to say: it is feasible. Even huge promised efficiency improvements remain marginal. Everything remains in the terawatt range.

Some believe that the solution lies in new nuclear power plants. It is true that they could alleviate the problem, as they would reduce the need for replacement electricity and help to cover additional demand. However, the scale of the problem is so great that the number of such power plants would place excessive strain on other resources.

For others, huge power plants should be set up in sunny areas and the electricity transported to the nearest coast, where huge hydrogen production plants would be set up. From there, the hydrogen could be transported to us.

But why? Wouldn't it make more sense to set up energy intensive industrial plants where electricity and hydrogen converge? For example: steelworks, chemical plants and the production of aluminium. This would also keep the transportation ways short and keep the grey note small in the green production.

Most of today's industrial plants would anyway have to be extensively rebuilt or even rebuilt from scratch for a hydrogen economy. Why not there? But that would change and shift the entire value-added chain as well as the international power structure.

It really looks as though green hydrogen is unlikely to become the global energy source of the future. However, local applications are certainly possible and meaningful. This is demonstrated by various projects, either already implemented or in the planning stage, on islands where wind and sun prevail and demand is limited to local residents and a small commercial and craft industry.

For such economies, there is no need for a hydrogen network of the size of the present gas network. It seems, that many, at least had a presentiment or even knew of this. The observed reserve on this has most likely up to now, avoided huge erroneous investments.

Wouldn't it make more sense not to view fossil fuels as culprits, but rather to value and respect them as valuable helpers? Or to rethink our consumption habits? Or to seek better sources of happiness than material excess? And also, to realise that the days of (too) cheap energy are over.

7. Summary

We have seen that the problem of using hydrogen to meet our energy needs and decarbonise the economy is not primarily a technical or technological one.

We know how to produce hydrogen. We also know how to transport and store it. We can also transform it into heat and electricity to meet our energy needs. The technologies for transforming it into other substances for everyday and industrial use as a substitute for fossil fuels have already been developed, are in the process of being developed, or have yet to be invented.

There is certainly still considerable room for improvement. This is important for the economic efficiency of the applications. However, it does not solve the fundamental problem.

The problem does not lie in the potentially limited application potentials of hydrogen. On the contrary, they are very diverse and tend rather to exacerbate the issue.

No, the fundamental problem is simply a question of scale. The demand for hydrogen is simply enormous. We need it as a substitute for fossil fuels and nuclear energy, which cannot be replaced by locally generated 'green' electricity. We also need it to cover the so-called winter electricity gap. We need it also for the transportation of goods and persons.

However, that is only the tip of the iceberg. Fossil fuels are not only energy sources, but also, and perhaps above all, suppliers of raw substances. If we want to do without them as part of the decarbonisation of the economy, oxygen and carbon must also be made available as raw materials alongside hydrogen. For most politicians, political scientists, business people, economists and many others, the simple calculation is: no problem, there is enough water, and we can get the hydrogen together with the oxygen in one fell swoop, and we can extract the carbon from the air. There is too much of it there anyway.

This means that, theoretically, we can produce the fuels, heating fuels and plastic products that we need.

The catch with this approach is that all these processes require a great deal of energy, mostly in the form of electricity, primarily in the form of 'green' hydrogen, that means produced with green power. The figures calculated for Switzerland give an idea of the scale of the expected quantities. They are not exactly encouraging for a global rollout.

So, in Switzerland, we need about 1.5 times our total annual consumption additionally to cover our electricity needs without fossil fuels and nuclear power. If we add to this the electricity required to produce fuels for transport, we need another 2 times our annual consumption. In 2024, this was 57.5 TWh.

The electricity production of hydrogen for the manufacture of relatively simple plastics such as PET, for example, is also in the TWh range. The situation is not much better in other countries, although the boundary conditions are different. The basic problem is the same.

A global hydrogen economy, as many dream of, could only be created by building huge solar or wind farms in locations where there is also plenty of clean water. Such locations are hard to find anywhere in the world; at least not where industrial centres are located. This raises the question of whether the old colonial model still makes sense or whether energy-hungry industries should be shifted to such locations. The transition to hydrogen would probably require most plants to be newly built or at least extensively renovated.

This means that such an economy is unlikely to be feasible. However, this does not mean that hydrogen will play no role at all in the future – quite the contrary. In isolated locations, i.e. islands in the sea, remote areas or regions with primarily domestic, commercial and craft energy consumption, it is likely to be among the top choices for a stable, local energy supply. A global hydrogen network will unlikely be the solution for that.

The calculated figures also show how inflated our economy is. The terms 'renewable energies' and 'decarbonisation of the economy' could burst this bubble. What alternatives do we have at our disposal? Do we need to come up with new economic and industrial models?

I hope this article has helped to clarify the issue and provide a better understanding of the topic. This would open the way to more realistic options that are free from dogma and political constraints.

Yours Jean-Pierre Rickli

September 2025

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