Energy
National Research Programmes 70 and 71

Project

Sustainability of methanation

Which is the optimal power-based fuel?

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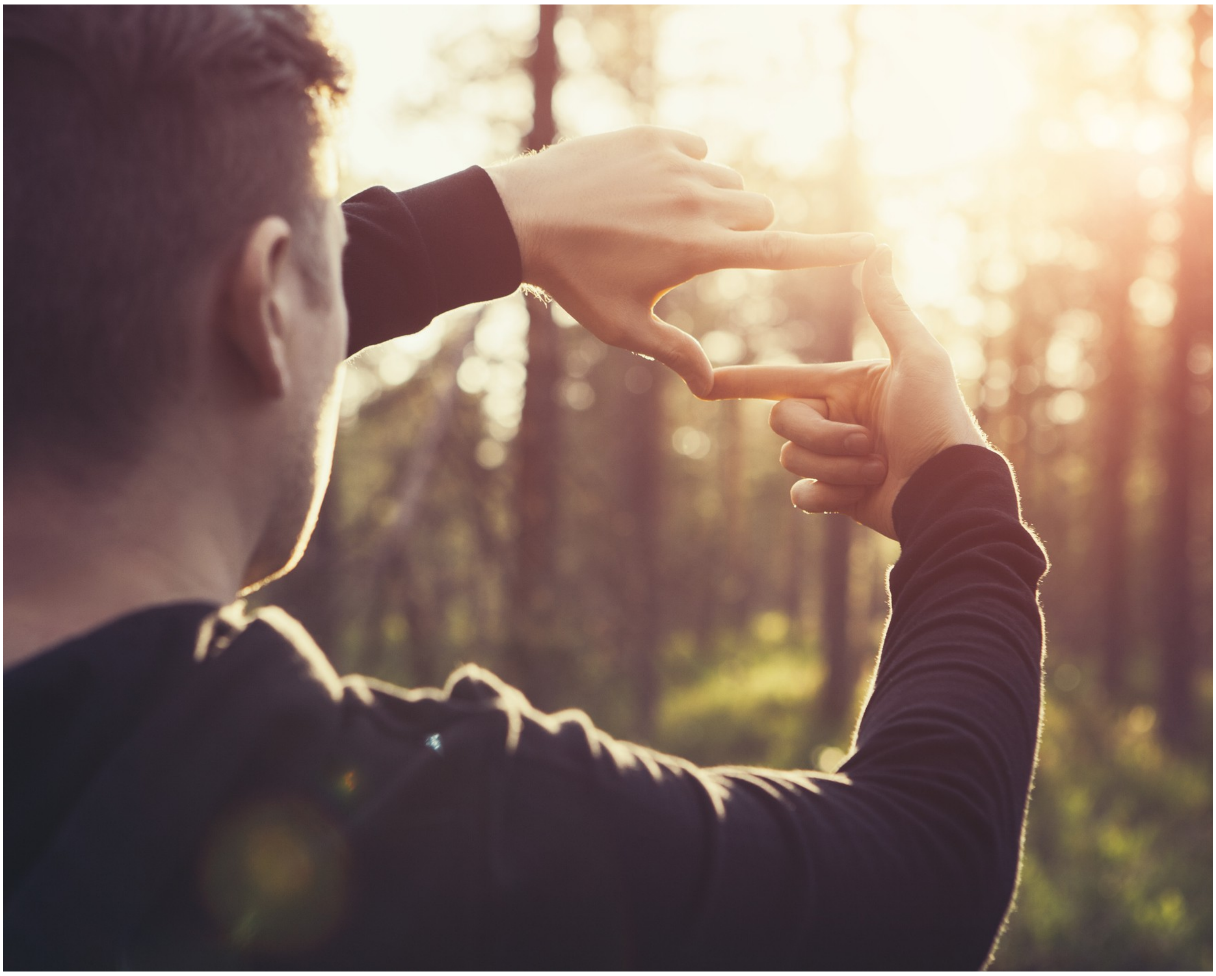
Before Switzerland decides which renewable energy carriers, such as synthetic natural gas and hydrogen, should replace fossil fuels, it is worth analysing all the options. The successful implementation of such a large project in Switzerland depends not only on the technical feasibility of the gas production, but above all on whether the applications can be used in an economically sensible and sustainable manner.



In the focus of interest: ZHAW researchers have tested the feasibility of a new value chain in Switzerland. *Source: iStock*

At a glance

- Greenhouse gas emissions can be reduced by replacing fossil fuels by renewable energy carriers such as synthetic natural gas or hydrogen.
- These can power not only cars and trucks, but also gas heaters or fuel cells.
- The switch to hydrogen and methane is sustainable only if the energy required for their production comes from environmentally friendly sources such as solar or wind energy.

In order to reduce greenhouse gas emissions, Switzerland intends to switch from fossil to renewable energy sources. Hydrogen and synthetic natural gas could play an important part in this process. Fuel cells can be used to exploit energy from hydrogen in systems both stationary and mobile (e.g. cars). With carbon dioxide and electricity, hydrogen can also be converted into methane. This creates a new value chain in which excess power is stored in the form of hydrogen or, with the help of CO_2, methane.

However, before investing time and money in the introduction of such an infrastructure, it is important to determine whether and how this value chain can be reasonably implemented in Switzerland. Researchers at the ZHAW have undertaken this assessment.

More than just a matter of technology

Generally, a conversion of this magnitude depends on more than just technical feasibility: all the required technologies exist, but they are still expensive or not yet developed to the extent that they can be used on a large scale. Furthermore, the success of a transition to a new energy concept also depends on its public acceptance.

Researchers have therefore examined the value chain not only in terms of its feasibility, but also in terms of its sustainability, i.e. environmental, economic and social issues. For example, photoelectrochemical water splitting is a climate-friendly technology for the production of hydrogen. However, the production of the fuel cells calls for metals mined in countries where social conditions do not meet Swiss standards. From a social point of view, this method is therefore sustainable only if the working and production conditions in the countries of origin of the metals are improved.

From hydrogen and CO_2 to methane

It all begins with hydrogen, which can be produced in two different ways: either directly by means of photoelectrochemical water splitting (PEC) or by means of classical electrolysis using electricity.

The hydrogen produced by these methods can then be converted either directly into electricity in a fuel cell or into methane using CO_2 from sources such as cement works. The renewable methane can then be used as an energy carrier in a gas heating system or a gas vehicle.

This value chain has a clear advantage over one depending on fossil fuels. The amount of CO_2 required for the production of methane is exactly equal to the amount released during combustion of the gas. The fuel itself is therefore climate-neutral and could help Switzerland achieve its goals for the Energy Strategy 2050.

Sustainable at all levels

For the evaluation of the value chain, the research team defined five different scenarios.

- **Basic scenario:** describes the current system. Fossil methane is used to produce electricity. CO_2 emission certificates are purchased to compensate for the negative effects on the climate.
- **Scenario 1:** hydrogen production using PEC cells in Switzerland, followed by further processing into methane in local reactors.
- **Scenario 2:** hydrogen production by means of an electrolytic procedure using electricity from photovoltaic power plants, followed by local processing into methane.
- **Scenario 3A:** the electricity for the production of hydrogen comes from surplus renewable

energy sources.

- **Scenario 3B:** the electricity for the production of hydrogen comes from the current electricity mix.

The environmental friendliness of the scenarios depends not only on how much CO_2 is released, but also on other influences that can affect the environment. In scenario 3B, for example, the electricity used to generate hydrogen stems from the current electricity mix. Approximately 35 percent of this mix is produced by nuclear power plants, which generate radioactive waste that needs to be stored safely for a long period of time, thus resulting in a negative impact on the environment.

The financial aspect also plays a part in whether a scenario can be successfully implemented or not. The cost analysis shows that in all cases costs in the order of tens of billions of Swiss francs are to be expected, except in the basic scenario. This is not surprising, since all other scenarios require the implementation of many new technologies. The costs are highest for scenario 1, since harvesting CO_2 from the atmosphere is an expensive procedure. In a further step, this CO_2 is then to be converted into methane using hydrogen generated by the yet insufficiently tested PEC technology. All in all, this leads to low economic sustainability.

Provided the baseline scenario is not taken into account, scenario 3A performed best in the area of economic viability. However, the amount of available surplus electricity being insufficient, new installations that can provide power from renewable energy sources are required. Scenario 3a is therefore the most favourable and theoretically the easiest to implement.

Not at all costs

The researchers have found that the comparatively few hours of sunshine in Switzerland are not optimal for generating electricity or hydrogen from solar energy. The production of the power needed for this procedure would require 100 km^2 of photovoltaic cells. Only by increasing the efficiency of these technologies can these scenarios become more sustainable.

In addition to technological developments, it is also important to consider the conditions under which raw materials are extracted. For example, new fuel cells require nickel from Indonesia. In this country, as in many others, transparency regarding working conditions is poor, making it practically impossible to issue clear statements concerning the social sustainability of the technology.

Direct usage or conversion?

In a final step, the researchers determined whether it makes more sense to use hydrogen directly as an energy carrier or to convert it into methane with the help of carbon dioxide.

Direct usage: hydrogen is a high-quality energy carrier that can serve many different purposes. It can be used to power both stationary and mobile fuel cells. Its main disadvantage is that the infrastructure for storage and transport within Switzerland has not yet been developed.

Conversion into methane: The greatest advantage of this approach lies in the existing infrastructure. This energy carrier can be fed into the well-developed Swiss gas network. The main weakness is the need to implement new technologies, which results in high installation costs.

Overall, the researchers conclude that a switch to this new value chain is sustainable only if it goes hand in hand with a shift towards energy production from renewable energies.

Produkte aus diesem Projekt

- A Cost Estimation for CO2 Reduction and Reuse by Methanation from Cement Industry Sources in Switzerland
  Date of publication: 01.01.18
- Social Life Cycle Assessment: Specific Approach and Case Study for Switzerland
  Date of publication: 17.12.18
- Life Cycle Assessment of Renewable Methane for Transport and Mobility
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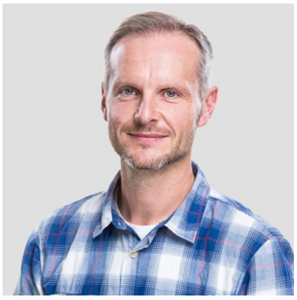

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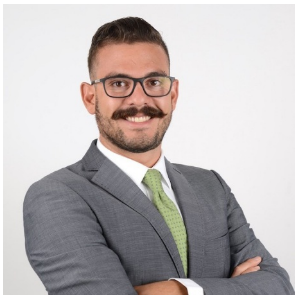

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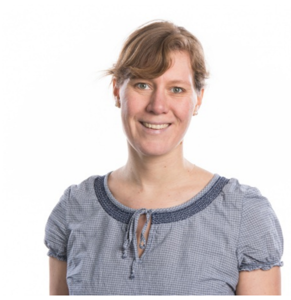

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Associated projects

Catalytic methanation

Renewable Methane for Swiss Winters

PEM fuel cells

Fuel Cells for Sustainable Mobility

All information provided on these pages corresponds to the status of knowledge as of 18.06.2019.