Heriburg's renewable future - proposals how to combine PV, electrolysis, metal hydrids and a block heating and generating plant to become independent and carbonfree

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Contents

Abstract

Our project " Heriburg's renewable future - proposals how to combine PV, electrolysis, metal hydrids and a block heating and generating plant to become independent and carbonfree" deals with the improvement of our school building. We tried to develop a concept that can be used at our school but also can be applied at other schools. For that we made the concept as climate- and environmentally-friendly as we can, to preserve our earth for a long time to come. In doing so we try to produce less carbon dioxide or other greenhouse gases, to improve our school's carbon footprint on earth. The project also considers renewable energies, hydrogen storage, block heating and generating plant and thermal isolation with hemp. Throughout the project, we ask ourselves how to mitigate the consequences of the climate crisis, the biggest climatic crisis humans have ever caused. With this project we are going to show where the problems of school buildings are which are often not at all or only weakly equipped with techniques that are climate- and environmentally-friendly. Through the project we do not only want our school/s to be carbon neutral, we also want to build an understanding of the climate crisis and educate fellow students. We want to be a role model for students and other schools.

 [1]

[1] The photo was taken by Mr Heskamp, a teacher at our school.

Introduction

We found out that our school will be renovated in 2022 to 2026 and that several millions of Euro will be spent by the city of Coesfeld; so for our project we have asked ourselves if our school uses any kinds of renewable energies and/or any kinds of climate friendly storage methods like hydrogen storage. And we found out that our school does not use many of these methods, like most schools.

For our project we try to make our school as renewable and as climate-and environmentally-friendly as we can. But what are problems, when we do not change our school in a good way? How can we feel it in Germany, but even more in other countries?

Climate change. That's the most common way of describing what´s going on in the world right now. But that's not the best word to use. When we use "Climate change" we sugarcoat. It is a euphemism. We have to call it what it is "Climate crisis".

The world is steadily getting hotter which at first doesn't sound too bad but it causes worldwide catastrophes such as melting glaciers, huge floods, the extinction of animals and fishes and other really big problems.

We in Coesfeld have had the privilege, that the climate crisis has not affected us in a big way for a long time. That's one reason why we didn't do anything about it. Lots of regions around the world are already extremely struggling because of the climate crisis. An example is Asia where the pollution is so bad, they are advised to wear a mask or in Greenland where the ice sheet is melting. Now, the climate crisis affects us as well. A good example is February 2021. In the shortest amount of time, the weather changed from snowing, raining and sub-zero temperatures to being sunny and warm.

Lots of people even deny in the climate crisis. The first thing to stop the climate crisis is to acknowledge that it is a problem, and that is what we did. We decided to take this in our own hands and come up with something we could do against the climate crisis.

Fossil fuels are one of the biggest causes, because they produce carbon dioxide. In high amounts Carbon dioxide is really bad for the atmosphere, as it is a greenhouse gas and there is a higher chance that infrared-radiation from the earth hits a carbon dioxide molecule if there are more of them in the atmosphere. This process of the natural greenhouse effect is actually not a bad thing, because without that, our Earth would be –18 °C and our Earth would be unlivable, but as more carbon dioxide and other greenhouse gases are contained in the atmosphere, the Earth gets hotter and hotter and that is really bad for the environment and for climate (man-made greenhouse effect).

On the one hand it is important to educate the students about the climate crisis, but on the other hand it is just as important to be a role model. That is why we try to create and use climate and environmentally-friendly energy.

After a long process of discussions, we have developed a concept that we can apply not only to our school, but to many schools in Germany and the world, therefore we tried to make it as easy and cost efficient as we can. Thereby lots of schools can be a role model for students, set a sign and fight against

the climate change by using our concept. In doing so, we want to change the following things that we have noticed at our school, but also at other schools.

Asking our school's facility manager, we found out that the electricity we get from the city of Coesfeld at the moment is created by non-renewable energies, thereby thousands of tons of carbon dioxide are created and blown into the atmosphere, so the probability that a CO_2-molecule is hit by an infrared wave (long waves) gets higher and the earth gets hotter and hotter. We found out that our school produced 8.5 tons of CO_2 in 2019. To no longer have to rely on this type of electricity we want to create our own electricity by using photovoltaic systems. We will explain why we have chosen this type of renewable energy in our main part.

Another big problem is the heating system: there are two types Heating modes we use at the moment. On the one hand the pallet heater that we will not replace, as it uses wood to create heat. Wood is a renewable energy that nevertheless produces carbon dioxide when burnt but this is carbon that is released into the atmosphere after being stored in the tree for maybe 20 years not millions of years. But on the other hand we use another, worse type of heating system: an oil heater. It uses natural oil and burns it to create heat, this process produces lots of carbon dioxide. To stop this process, we need to replace the oil heating system by a “block-type thermal power station”. This multi-functional system can be used as a heater with the help of hydrogen and is detailed explained in our main part.

To ensure good thermal performance in the building, we need good thermal insulation. As our school was built in the 1970s we need insulation to be installed because there is none. If we do not insulate our building we will continue to have a huge heat loss and we will need unnecessarily much hydrogen for heating that we could use differently and more efficiently.

But we also need a system that can create hydrogen (electrolysis) and that can create energy with hydrogen (fuel cell). The PEM-cell is perfect choice because it can both, thus we have more space for other systems described before.

There is only one question left. Where can we store the hydrogen created by electrolysis? We will have metal hydrids. But what are benefits of this kind of storing? This question we will answered in our main part.

In a nutshell: We are trying to replace old, non-renewable energies with new, renewable energies that can slow down the climate crisis, we want to change our heating system and take electricity production into our own hands and use hydrogen to store the created energy.

Photovoltaics

A perfect alternative to fossil fuels is photovoltaics that can produce electricity. We will use one part of this electricity for our normal consumption (computers, lights etc.) and the rest for electrolysis. But before we talk about why we have chosen this kind of renewable energy; we have to talk about how it works.

But before we speak about solar panels, we have to know what an atom looks like.

An atom consists of an atomic nucleus and the atomic shell. In the atomic nucleus there are protons (positively charged) and neutrons (neutrally charged). In the atomic shell there are the electrons (negatively charged). In the atom there are as many protons as electrons, so the whole atom is neutrally charged.[2]

Next, we need to talk about photons. photons are little energy ``balls`` in the light, these photons can release electrons.

The solar panels consist of silicon (4 electrons on the outer shell), boron (3 electrons on the outer shell) and phosphorus (5 electrons on the outer shell). The solar panels have two layers, the first layer consists of phosphorus and silicon. The second layer consists of silicon and boron. The phosphorus atom gives one electron to the boron atom, so every atom has 4 electrons on the outer shell. Furthermore, the charge has moved, the first layer is positively charged (there are more protons than electrons) and the second layer is negatively charged. If the sun shines on it, the photons release the electrons from the boron, this released electron is attracted by the positively charged first layer. If you put a conductive metal over the first layer, the electron goes over it into an external circuit. These moving electrons light a lamp. [3]

The biggest disadvantage is that we need an inverter, as the photovoltaics system creates direct current but if we want to use it in our sockets, we need to have alternating current. The inverter can transform this direct current into alternating current.

But why have we chosen this kind of renewable energy? Photovoltaics is one of the most common renewable energies in Germany for houses. They have become more affordable in recent years. Our roof needs a renovation and the work can be done at the same time. Our roof is very big, flat and rectangular so it can offer much space for solar panels. Furthermore, photovoltaic systems are very good at value for money and produce a lot of electricity on a sunny day. In addition, the system does not produce any noise and smell, so it is perfectly for students to be able to continue learning.

[2] Das Atom, by Alexander Giesecke and Nicolai Schork, 6.12.2016
https://youtu.be/BqeSHBgIRWI

[3] Wie funktioniert eine Solaranlage?
https://www.solaranlagen-abc.de/funktion-photovoltaik/

PEM-cell

In an electrolysis cell we can create hydrogen but we also need a fuel cell to create electricity with the hydrogen created by electrolysis. In our project we have chosen a PEM-cell. But what is electrolysis and a fuel cell and what can we do with it?

Electrolysis is a chemical decomposition produced by passing an electric current trough a liquid or solution containing ions (in our case: water).[4]

Thereby water is transformed into ions: OH^- (hydroxide) and H^+ (hydrogen-ions) [5]

$$H_2O \rightarrow OH^- + H^+$$

A fuel cell is an electrochemical cell that converts the chemical energy of a fuel (here: hydrogen) and an oxidizing agent (here: oxygen) directly into electricity through a pair of redox reactions. So a fuel cell is a direct transformation from chemical energy into electric energy (here: electricity).

But why have we chosen the PEM-cell? The biggest advantage of the PEM-cell is that it combines the electrolysis and the fuel cell in one. To understand this, we have to understand how an PEM-cell works. In the first part hydrogen is created: here the positive pole (-) is the anode. The water is added at the anode. In the PEM-cell there is a membrane which only allows hydrogen ions (H^+) to pass, the electrons must be transferred via the external circuit to the cathodic side (negative pole (-)). The oxygen is drained. On the cathodic side 4 electrons and 4 hydrogen ions reacts to 2 hydrogen molecules.

$$+ \text{ oxidation: } 2H_2O \rightarrow 4H^+ + 4e^- + O_2$$

$$\text{-reduction: } 4H^+ + 4e^- \rightarrow 2H_2$$

$$2H_2O \rightarrow 2H_2 + O_2 \quad \text{endothermic}$$

The counter-reaction, the fuel cell takes also part in the PEM-cell. The hydrogen molecule is inserted on the anodic side (minus pole (-)). The membrane again allows only the hydrogen ions (H^+) to cross. The electrons only reach the cathodic side via the external circuit, if you connect a lamp to this circuit, it starts to glow, because electricity is only moving electrons. On the cathodic side (plus pole (+)), 4 electrons and 4 hydrogen ions (H^+) react to 2 hydrogen molecules. The two hydrogen molecules react with the air/oxygen (O_2), that is fed, to two water molecules. [6]

$$\text{-oxidation: } 2H_2 \rightarrow 4H^+ + 4e^-$$

$$\text{+reduction: } 4H^+ + O_2 + 4e^- \rightarrow 2H_2O$$

$$2H_2 + O_2 \rightarrow 2H_2O \quad \text{exothermic}$$

[4] Electrolyse
https://de.wikipedia.org/wiki/Elektrolyse

[5] Der ph-Wert- chemische Grundlage
https://klassewasser.de/content/language1/html/3696.php

[6] PEM-Brennstoffzelle
https://www.tuvsud.com/de-de/indust-re/wasserstoff-brennstoffzellen-info/brennstoffzellen/

The anodic and cathodic sides alternate, since oxidation always takes place at the anode and reduction at the cathode.

The big advantage of the PEM-cell is that we do not need two machines for the electrolysis and the fuel cell, but only one machine that can do both. This saves us space that we can use in other ways.

More electricity than consumption

Hydrogen is a really interesting chemical element; it is used in fuel cells to generate energy. This generation is silent and way more efficient than our current use of fossil fuels as energy producer. Fuel cells are used to provide energy (for example heat) via a chemical reaction that produces water and energy. This process does not produce any carbon dioxide or any other greenhouse gases (like methane).

The best hydrogen to use is so-called "green-hydrogen", it is created by electrolysis with green energy (in our case photovoltaics) when the production of the photovoltaics system is higher than the demand. This hydrogen offers a possibility to store the excess of the energy that is not used. When the demand is higher than the production (e.g. it is night) the hydrogen that is stored can be used to produce electricity in a fuel cell. We will discuss our storage method later.

Hydrogen gives us a new opportunity to store the electricity generated by renewable energies.[7]

Metal hydrids

Hydrogen gas has the lowest density of all elements (0.08988 g/L)[8]

But how can we store an element with such a low density?

1. Store the hydrogen in a tank with high pressure (350-700 bar)
2. Store the hydrogen as a liquid at -252.8°C
3. Store the hydrogen in a metal hydrid

In our project we have chosen metal hydride storage to store our hydrogen.

In this process hydrogen is solved in metal or a metal alloy. The chemical combination of the two substances leads to a metal hydrid. The most important metal hydrids are: magnesium hydride (MgH_2), lithium hydride (LiH), sodium hydrid (NaH) and ammonia borane (BH_6N). The hydrogen is expelled from the metal hydride by lowering the pressure and applying a slight amount of heat.[9]

[7] Unlocking the potential of hydrogen energy storage
https://www.fchea.org/in-transition/2019/7/22/unlocking-the-potential-of-hydrogen-energy-storage
[8] hydrogen
https://en.wikipedia.org/wiki/Hydrogen
[9] Metallhydridspeicher
https://de.wikipedia.org/wiki/Metallhydridspeicher

The metal hydrid we have chosen is the ammonia borane (BH_6N). the ammonia borane has a high density of 780 kg/m^3, so it is easy to store it in large quantities.[10]

But this high density is also a problem if you want it to use it in a vehicle, the vehicle gets too heavy and it cannot be moved at all /only with difficulty. This problem we do not have in our house, because we do not have to carry the tank and the space is available in the cellar where we have our oil tanks at the moment.

Another big advantage of metal hydrids is that we do not have to build up pressure or a very low temperature to store the hydrogen.

Block heating and generating plant

For our project, we would buy a block heating and generating plant (BHKW) [11]from a company called Wolf[12]. It is cheaper than a fuel cell and it is more robust, so it will not break so quickly.

The costs of a 50 KW establishment is around 80 000€, but currently, subsidies are available for fuel cell heating, we could apply for funding and could expect around 10 000€ contribution.[13]

If our school needs more electricity than the photovoltaic system produces, for example when the sun does not shine or in the morning when there is not already enough sun, then the hydrogen, produced by the PEM-cell is put into the block heating and generating plant.[14] This establishment uses the hydrogen as the fuel, to drive the power station. We use our own hydrogen that we produce in the PEM-cell so we do not have to buy the hydrogen and it is produced without any production of carbon dioxide, so it is cheap and advantageous for the climate.

In the block heating and generating plant, we can produce electricity and heat, so we don't have to use an oil-or gas heating, like we still do now. So, we would replace the oil-heating with the block heating and generating plant and we would stop producing carbon dioxide with the way we heat. We also do not have to buy any gas, hydrogen or anything else. The block heating and generation plant burns the hydrogen-like a fuel cell and during this process, it creates the heat, too. With the produced energy by burning the hydrogen, a generator changes the energy into electricity, that we can use, whenever we need electricity.

The BHKW is useful for us, because while producing electricity or heat, there is no trash produced, the waste product is only water. We do not produce any carbon dioxide, it is climate friendly. Because of our PEM-cell, we know where the hydrogen is from and in producing the hydrogen, there is also no carbon dioxide produced.

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[10] Ammoniakboran- Amonia borane
https://de.qaz.wiki/wiki/Ammonia_borane

[11] German: **B**lock**h**eiz**k**raft**w**erk

[12] https://www.wolf-ps.de/

[13] Call with the Wolf- company

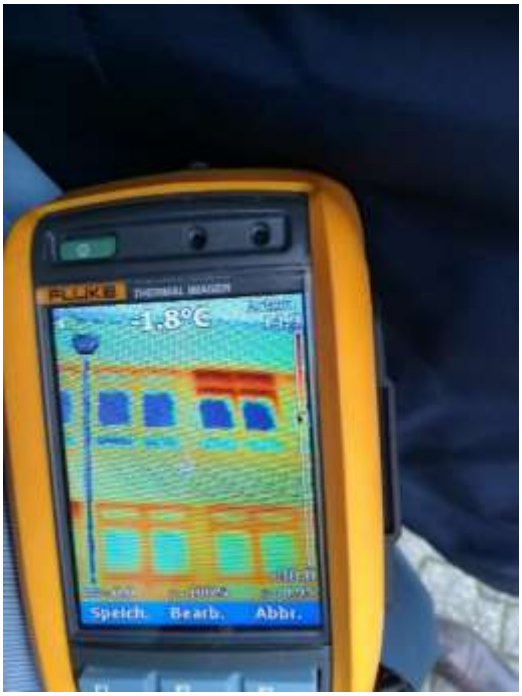
[14] Der Unterschied zwischen Blockheizkraftwerk & Brennstoffzelle
https://www.heizungsfinder.de/brennstoffzelle/heizung/bhkw-versus-brennstoffzelle

Thermal Insulation

Warmth always goes where it is cold. Outdoors in winter and indoors in summer.

When a body is at rest but still emits energy (heat), this is called heat conduction. Thereby, fast particles transfer energy to other particles trough collisions, so this energy also reaches cold places.[15] Heat can come through walls, windows and roofs, the U-value describes the heat transfer trough a building component. The U-value is measured in watts per square meter and Kelvin W/(m^2K). The better the thermal isolation, the lower the U-value.[16]

Our school has a high U-value which means that the heat goes outside (in winter), this can be seen picture no.2. With this thermal-imaging camera, Infrared-radiation is made visible. That allows us to see where it is the hottest. The biggest problem, with that, is that we lose a lot of heating energy (approx. 20% or more).[17] This energy we lose, we could use more efficiently.



[18]

[15] Ausbreitung Wärme
https://www.grund-wissen.de/physik/waermelehre/ausbreitung-von-waerme.html
[16] Bei Haussanierung den U-wert einhalten
https://www.effizienzhaus-online.de/u-wert/
[17] Wo und wie geht Wärme im Haus verloren
https://www.baulinks.de/webplugin/2010/1212.php4
[18] This thermal picture was taken in November 2019 during our project week "Heriburg for Future". It shows that we lose energy because of no insulation.

Through all these negative points, have we decided to install a new thermal insulation. Therefore we have chosen hemp fiberboards, these consists of 85% hemp and 15% polyester fiber.[19] It has a very good heat rating and a relatively low price (3.76€ per m^2).[20]

The water that is needed for hemp is very low (2.1 L/kg), for comparison, a cotton plant consumes approx. 9.7 L/kg.[21] Low water consumption is essential for an environmental house.

In addition the plant grows fast and does not need fertilizer or pesticides that is bad for the environment and the animals. [22]

Costs

For our project, we would have to buy: a photovoltaic system, a block heating and generating plant, two PEM-cells stacks and the material for the thermal insulation.

For the photovoltaic system, the costs behavior around 196 205€[23] when we have too much excess electricity we could sell it to the grid (9-13 cent per kwh).[24] The costs for the block heating and generation plant would be at 50 000€[25], but we could apply for support of 10 000€so we would need to pay 40000€. We would buy two PEM-cells and they would cost around 60000€ (30000€per PEM-cell)[26].The costs of thermal isolation would be in the amount of 2400€.[27] All together our project would cost around 298 606€

[19] Die besten Dämmstoffe im Vergleich
https://www.my-hammer.de/artikel/die-besten-daemmstoffe-im-vergleich.html

[20] Thermo Hanf Premium 120 x 58 x 3 cm - 20 Platten (13,92 m²)
https://www.baunativ.de/product_info.php?products_id=4367&language=de&gclid=CjwKCAjw6fCCBhBNEiwAem5SO87DM4-1TR62mEWKJlnvGc5fqkXsVLSoBukgm-A0kOBy2d7qn40SbRoCJhgQAvD_BwE

[21] Hanf und Baumwolle: Welches Textil ist besser?
https://www.royalqueenseeds.de/blog-hanf-und-baumwolle-welches-textil-ist-besser-n1087

[22] Naturfasern aus Hanf-wie geht das?
https://www.vaude.com/de-DE/Herren/Eco-Fair/Nachhaltige-Materialien/Hanf/

[23] Der beste Weg zur Solaranlagen
https://www.verbraucherzentrale.nrw/wissen/energie/anschaffung-und-foerderung-kostenfragen-zu-sonne-im-tank-22559

[24] Anschaffung und Förderung
https://www.verbraucherzentrale.nrw/wissen/energie/anschaffung-und-foerderung-kostenfragen-zu-sonne-im-tank-22559

[25] Wasserstoff als BHKW-Brennstoff
https://www.topagrar.com/energie/news/wasserstoff-als-bhkw-brennstoff-10188657.html

[26] Experten Ratgeber: Technik und Anwendung von PEM-Brennstoffzellen
https://www.energie-experten.org/heizung/brennstoffzelle/typen/pem-brennstoffzelle

[27] Thermo Hanf premium
https://www.google.de/search?q=hanf+d%C3%A4mmstoffe&sxsrf=ALeKk00hHX9SUnAS2vnLRgwD2Lvahy3toA:1618407600474&source=lnms&tbm=shop&sa=X&ved=2ahUKEwik1IKR7v3vAhU0_7sIHQOvASoQ_AUoAXoECAEQAw&biw=1184&bih=535&dpr=1.62#spd=6287524781677310234

Conclusion

“You are never too small to make a difference”[28], this is a quote by Greta Thunberg, a famous climate activist. We need to act now and it does not matter how small you are, because we can make the difference. Even as a school we have to fight against the climate crisis. Thereby we are a role model to make others aware of the climate crisis. Our earth was always taken for granted us, although it is not. It is the choice of humans if we want to change our life, it is our choice if we want to continue to destroy our planet until we cannot stop it. It is our fault that we are in this situation and it is our duty that we protect our earth by using climate- and environmentally- friendly options. This transformation is so important and long overdue. We in Germany have had the privilege that the climate crisis did not affect us in a huge way, but there are many climate refugees whose lives we have destroyed by our excessive production of carbon dioxide in industrial countries. But we will not have this privilege of any longer if do not stop producing as much carbon dioxide as we produce now. Already now there are droughts due to the climate crisis. Even as a school we can help stopping this process by using our concept described in the main part when the architects plan our school's renovation in the coming months.

Sources

Use the links in our footnotes.

[28] Greta’s speech at the climate conference in Poland
https://youtu.be/VFkQSGyeCWg