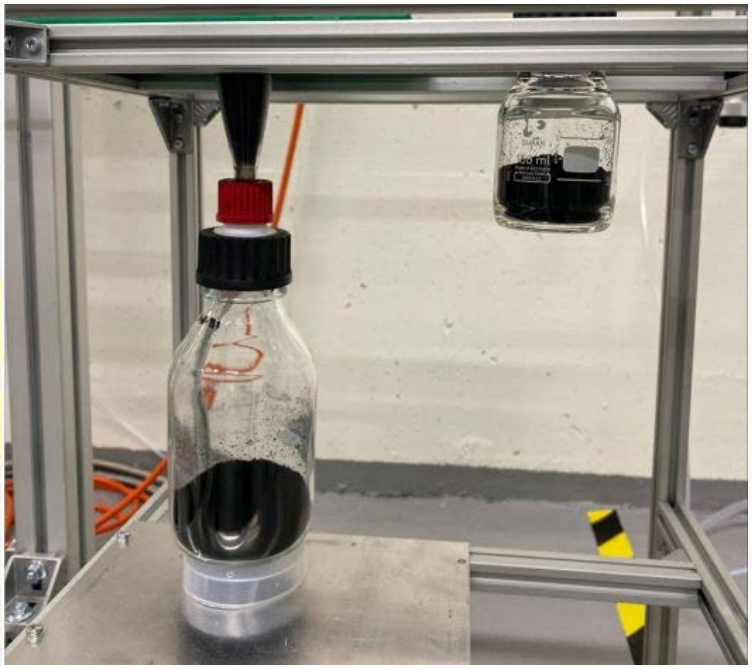

## ColdSpark® results: how far we are?

ColdSpark® project aims to pioneer and validate a groundbreaking plasma reactor capable of efficiently producing elemental carbon and hydrogen from methane, all while maintaining a low energy cost of 15 kWh/kg $H_2$ produced, and without reliance on catalysts or water.

Having **successfully tested the innovative plasma reactor at a lab scale**, the project now progresses to the crucial phase of validating the process at a **demo scale**. This step will be undertaken in conjunction with optimising the power supply, with the overarching goal of achieving the industry's most power-efficient generation of hydrogen alongside the

production of high-value pure elemental carbon. The project's next milestone involves designing, testing and optimising the industrial-scale reactor. This reactor will leverage the best features of non-thermal plasma technologies, specifically the gliding arc and corona discharge methods, to ensure both high efficiency and scalability.

As the project continues to forge ahead, significant attention is directed towards the **analysis of carbon samples** generated through the innovative plasma reactor. These initial results serve as a crucial foundation upon which the project team can evaluate and determine the most effective strategies for **carbon exploitation**.


Certificate of registration
of trademark

Registration number: 329212

eCarbon

Holder: SEID AS
Filing date: 2023.09.07
Mark type: Word mark

Your trademark is registered and entered in the Norwegian trademarks register in accordance with the Norwegian Trademarks Act of 1 July 2010.

Kathrine Myhre
Director General

Gjør ideer til verdier

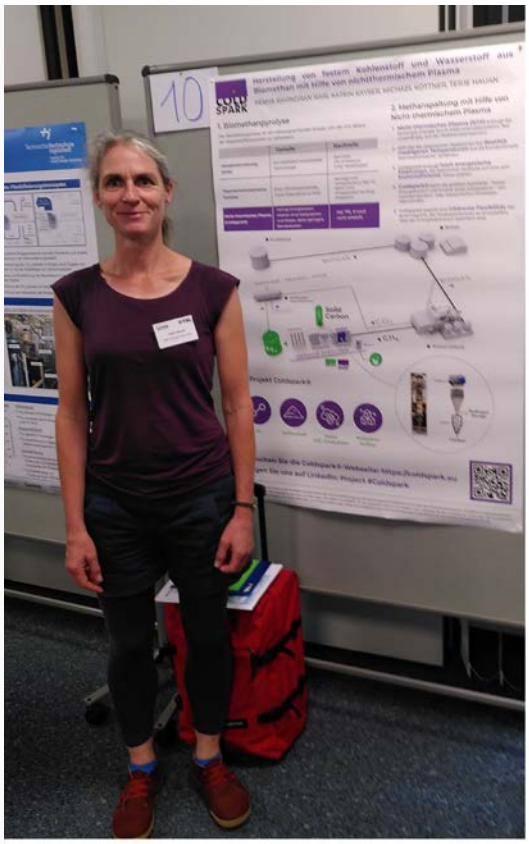
Norwegian Industrial Property Office

On the path to it, an "eCarbon®" trademark was received by the project coordinator SEID AS, which solidifies their proprietary on elemental carbon, produced through our innovative ColdSpark® process, as a sustainable and high-performance material. eCarbon® will find its application in various industries, including batteries, coatings, silica, and steel.

By reaching TRL5, the project will signify a significant advancement in plasma reactor technology, paving the way for more sustainable and efficient energy production methods.


## ColdSpark® technology in the eyes of the end-users: questions and benefits

### Interview with Michael Köttner and Katrin Kayser (IBBK)





*Biogas Network (IBBK) was founded in 2000 and consists of a network of over 9000 biogas and biomethane plants in Germany. IBBK provides consultancy services for economic efficiency to the industry operators, organises conferences and trainings. In ColdSpark® one of the main roles of IBBK is to support the demonstration of the opportunity for the plants to shift to H2 production and the eventual commercialisation among its members, as well as C&D activities.*

***Galina Ivanova: So far, IBBK has presented ColdSpark® at various events, ranging from smaller training sessions to major conferences in the energy sector. Could you share insights on the overall feedback from potential users and how they perceive the potential applications of ColdSpark®?***

***Michael Köttner:*** The questions we received were around the technology. A lot of people I met, were aware of plasma technology, but they were not aware of the ColdSpark® pulsed plasma. Also, they weren't aware that we are working with much lower temperatures around 200–300°C compared to methane cracking technologies over 2000 °C.
I also met specialists who said that they tried to split methane, but it didn't work. In Germany, hydrogen production from biogas is quite well known now and we have an existing steam reformer that splits biogas into hydrogen and $CO_2$. There is already a small-scale plant that is cracking at a biogas plant offering biohydrogen from biogas. The company is called BTX Energy; it is working together with the University of Aachen. Another option is thermal methane cracking, with Graforce as a company in Berlin more advanced in this field.
ColdSpark® is different. We are producing low-carbon hydrogen at low temperatures and pressures less than 5 bar, but then we are also producing solid carbon. And this is, of

course, the major difference and makes it very interesting to compare and to say, well, we have this advantage that we are solidifying the carbon and it's not escaping as $CO_2$ into the atmosphere.

***Katrin Kayser:*** Michael is more often on very high-level conferences with many representatives from industries, whereas I am more in the biogas sector. In Germany, this is more of an agricultural setting, not so much an industrial one. People now are aware of hydrogen; it is becoming normal today compared to some years ago. But the idea that there's no $CO_2$ emission from the process, is novel to most of them. I find it takes a bit of time to understand for someone who has never heard about this approach before to digest this info and to see the opportunity in this. For someone who's operating a biogas plant and who's maybe looking into future perspectives, the interesting questions are, of course, the same as Michael mentioned. Plant operators are interested in the technical readiness level of the technology, how much will it cost, and when will it be available. I also must explain what a non-thermal plasma is.

The persons I talk to want to know then more about solid carbon, what it exactly is, and what one can do with it. They are interested in the quality of the carbon received. Now, after the technical experiments conducted, we have some of the answers to their questions and know that we will receive a very high pure carbon, which is mostly used in the tire industry.

Another question that also shows up is about the purity of the hydrogen and whether it is suitable for the transportation sector. Now, we can answer that the hydrogen, which is coming out of the PSA unit will be very pure hydrogen quality. After the plasma reactor, we have a carbon cyclone collector in the lab scale unit. While upscaling, we will also incorporate a bag filter. So, there will not be any carbon in the hydrogen.

***Galina Ivanova: We already touched on my next questions - what are the key strengths and advantages of ColdSpark® technology that set it apart from all the other solutions in the energy sector? We have a lot of emerging technologies that compete for a place.***

***Michael Köttner:*** The innovative plasma technology used in ColdSpark® operates at low temperatures and pressures, resulting in a significantly lower energy cost, which makes it economically attractive for the end-users. When the system is fine-tuned, its efficiency will surpass other methane cracking processes in the market with a high level of methane conversion rate. Pairing the plasma reactor with an advanced power supply with high energy efficiency will allow precise fine-tuning of the cracking process parameters. This results in an overall plasma system energy efficiency, surpassing current SMR processes and other methane cracking technologies. Another advantage is that in ColdSpark®, we are not using any catalyst to lower the temperature, and there is no usage of water.

I think it's a key technology for decarbonising, especially if you want to continue using natural gas or even biomethane. Natural gas can be decarbonised, and biogas even more, because it can become carbon negative.

As there are no $CO_2$ emissions, I think this is one of the key technologies for

decarbonisation, especially in the light of Norwegian energy supply and Norwegian gas extraction, where we have very low $CO_2$ emissions for electricity and very low $CO_2$ emissions for methane extraction. Here we have very low carbon emissions. And on top of that, we can decarbonise the natural gas. And that is quite an asset, I think, to take away $CO_2$ from natural gas and the atmosphere when using biogas. That brings us towards the EU goals.

***Galina Ivanova: That was actually my next question. In light of the EU's climate goals, how do you envision ColdSpark® contributing to and supporting the achievement of these objectives?***

***Katrin Kayser:*** The strongest selling point of ColdSpark® is the solid carbon instead of $CO_2$ production. We have discussed this within the project, but I also find this in my immediate communication with the end-users. When we look at the chain from raw biogas, which is a mixture of methane, carbon dioxide, and some other gases, hydrogen sulfide, for example, we have to clean the biogas, upgrade it to biomethane, which means we remove $CO_2$ and other trace gases. One question that also pops up from the biogas plant operators is, why do I want to use the biomethane for hydrogen production? If I have biomethane as a product that works well in transportation, it's easy to handle, to market and to use. We have an existing infrastructure and so on. And while the argument is to produce solid carbon and hydrogen instead of $CO_2$ and hydrogen, we still have this biogenic $CO_2$ that comes with the raw biogas and needs to be used or stored.
So, for the biogas sector, we think about operators who might be interested in installing such technologies. One reason for this is that biogas has a little bit of a – I would say – “dirty” image at the moment because there are also $CO_2$- and to some degree methane emissions. Hydrogen is perceived to be much cleaner. So, if convert the biogas into hydrogen and solid carbon and we even remove more $CO_2$ than we produce, then biogas can have a better image through that. Biogas is already renewable, but then through converting the biogas into carbon and hydrogen, it becomes a truly clean and sustainable source of energy.

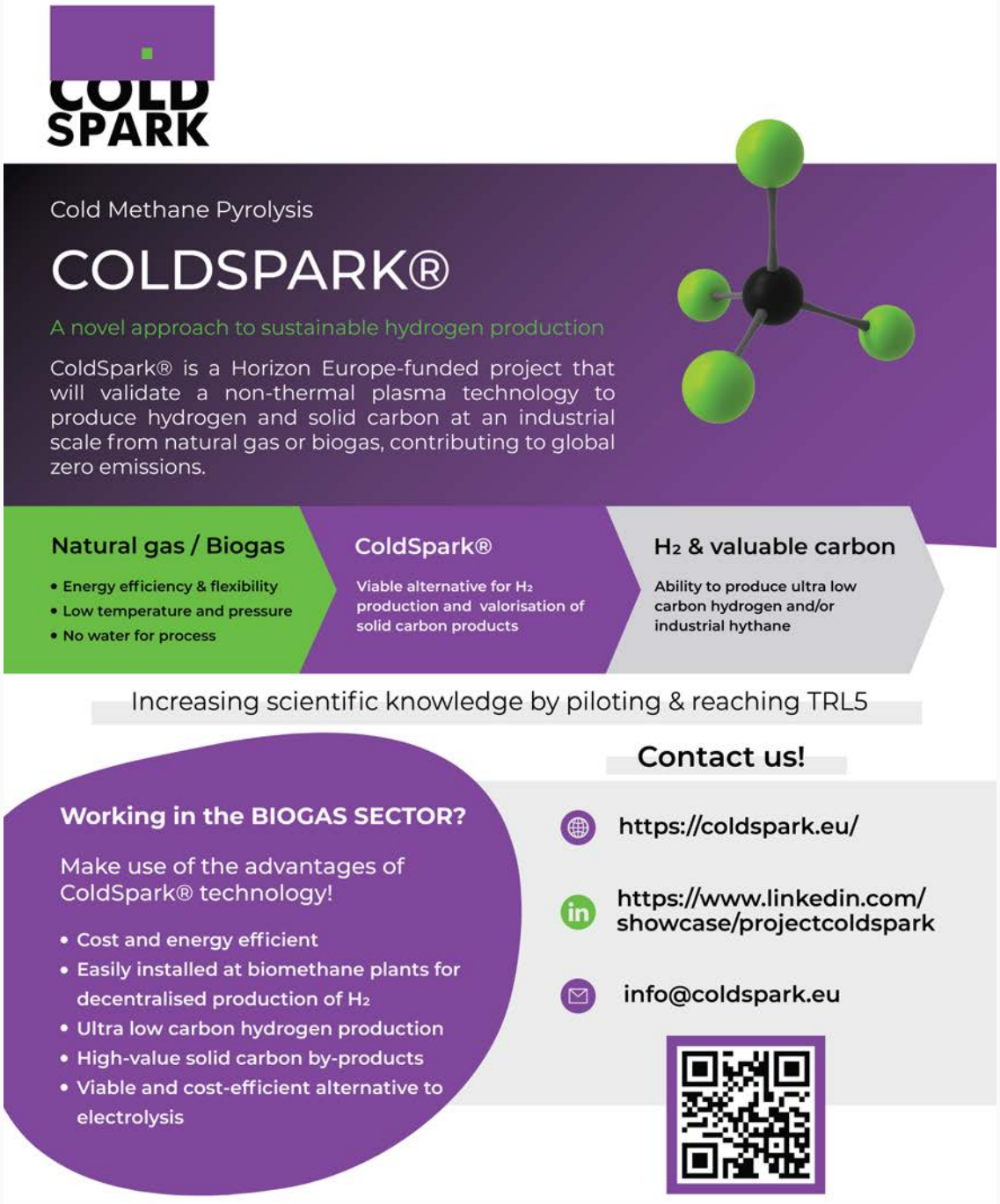
***Galina Ivanova: Knowing the ColdSpark® end-users, can you also name some obstacles in the application of the ColdSpark® technology in the biogas sector? Can you anticipate some problems that could appear on the way? Something that we can address even now.***

***Michael Köttner:*** Well, the obstacles are connected to the scale. On a larger scale, we are going to build up the ColdSpark® technology next to the natural gas pipeline, where unlimited amounts of natural gas are coming out. In a biogas plant we have a gas flow of, let's say, 200 cubic meters of methane per hour on average, and natural gas has thousands of cubic meters per hour. Will this technology be suitable for smaller-scale applications is a big question? And that also is a question from the participants of the industry. Will it be suitable for small-scale biogas and small-scale gas flow?

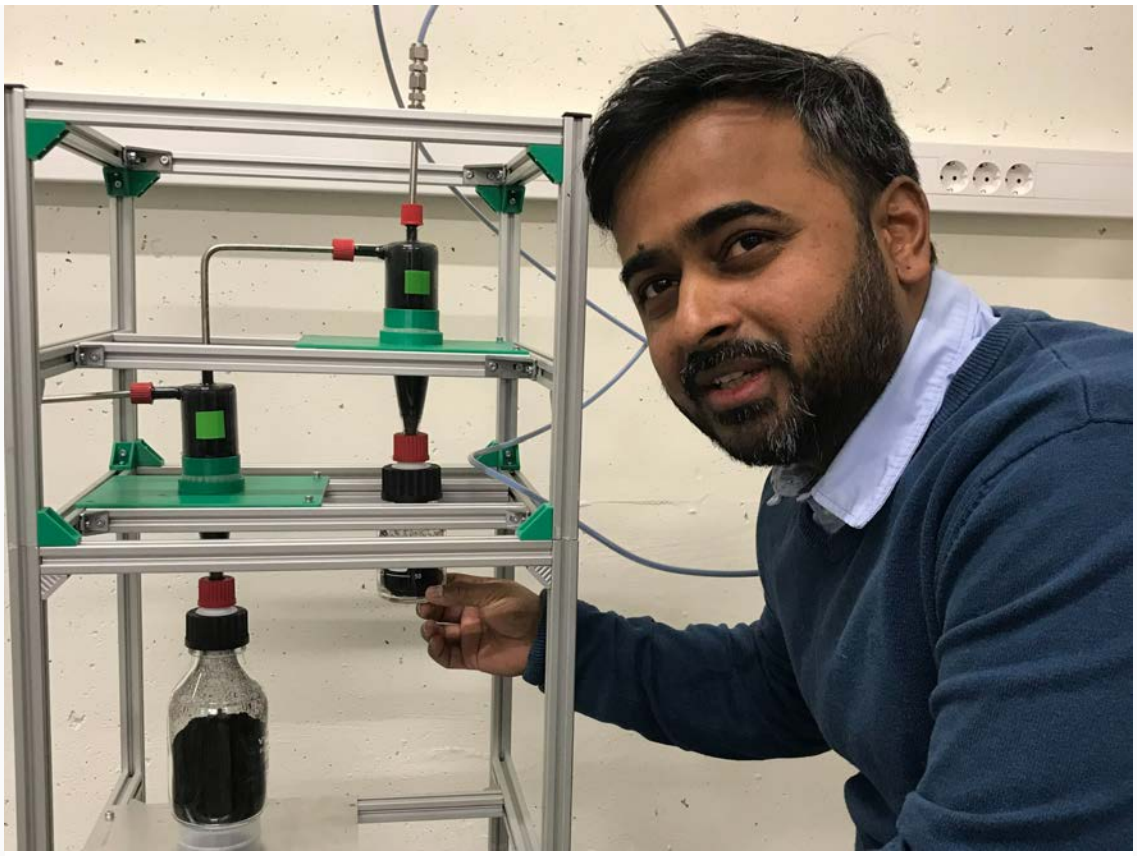
***Katrin Kayser:*** The product stream at one single anaerobic digestion plant is usually small compared to the needs of an industry. Another topic is the marketing of the products. The electricity sales are easy, technically easy. The heat use is also simple, once a heating grid has been established. How would this look for the hydrogen and the carbon? Who will be an intermediate? Who will collect the product? And so on.

***Galina Ivanova: My last question is what is your personal and company motivation for taking an active part in the ColdSpark® project? How does the ColdSpark® project align with the IBBK vision for future development?***

***Michael Köttner:*** Well, we are doing a lot of networking and providing services to the industry. And hydrogen is really on the top cards with all the renewable gases. Biohydrogen at the moment, is the only feasible option, in my opinion, to produce hydrogen at reasonable costs. In fact, Low-carbon hydrogen at reasonable costs. And I cannot see any other technologies being more advantageous at this moment than methane pyrolysis. Everything else is too expensive and it's too inefficient. It is very, very energy inefficient. We have to spend a lot and a lot of energy, a lot of electrical energy, a lot of catalysing energy to convert and to produce hydrogen. And if I'm thinking about our German government, for instance, which plans a big hydrogen facility in Namibia with solar energy. So, you put up solar panels, you produce the electricity in a country where we have no electricity for the population. Then with that electricity, we partly have to make clean, ultra-clean water from sources, let's say from seawater. We have to pipe seawater to that site. That seawater is then desalinated and only used for hydrogen production, whilst 80 percent of the young people there don't have access to drinking water. Bringing the hydrogen to Europe is another question, a very big question.
With ColdSpark®, we can take the methane out of the grid in an established way, we can convert it to hydrogen and we can at the same time decarbonise the pathways. It has much more of a practical future. This is a feasible, decentralized solution. It can be installed near a gas pipeline or a biogas plant, take the gas, convert it to hydrogen if you want to have hydrogen. And if you don't want the hydrogen, you just want methane, you burn the methane. So, you have all the options and you have possibilities with that, and that I think makes it a very attractive solution. Also, it's decentralised and can be done everywhere where biogas plants are and where gas pipelines are. I think it is a very big asset to follow up.
***Katrin Kayser:*** For me, the ColdSpark® project is interesting because it strengthens my knowledge and capability to see different perspectives for the anaerobic digestion sector. And to relate this also to our national or maybe European politics. IBBK is a service company, which spreads knowledge to the biogas sector, therefore to see different types of solutions for the anaerobic digestion sector, and to be able to evaluate what makes sense, where are the benefits, and what is maybe theoretically interesting, but practically difficult.




## Unlocking the Carbon Potential in ColdSpark® Project: Pathway to Economic Sustainability



*In ColdSpark® project, Prof. Sachin and the Functional Materials and Process Chemistry Group are responsible for management of impurities and separation technologies, as well as for the carbon samples characterisation. With extensive experience in advancing materials for clean energy and environmental applications, they are a trusted scientific partner and adviser in identifying optimal exploitation opportunities. Specialising in inorganic, physical, materials chemistry, and chemical engineering, their expertise extends to gas storage, separation, and purification, prioritising clean energy solutions. Employing diverse synthesis methods and analytical techniques, they explore the structure-property-performance in materials bridging the gap between science and its practical applications.*

In the dynamic landscape of energy technologies and specifically in hydrogen production, the ColdSpark® project is making strides towards the industrial scaling-up of a simple and effective methane cracking technology to receive two valuable products: **hydrogen** and **elemental carbon**. The exploring of exploitation pathways for carbon in the ColdSpark® technology is particularly important, especially when considering economic sustainability and competitiveness in comparison to other technologies.
As a result of the ColdSpark® methane cracking process, for every kilogram of hydrogen produced, almost three kilograms of carbon are generated. The challenge lies in ensuring that the surplus carbon is separated and utilised effectively.

Highly valuing the opportunity for carbon application, the ColdSpark® project team is carrying out a **comprehensive analysis of the carbon samples** received. It is conducted by the University of Stavanger team led by Prof. Sachin Chavan. For the analysis, a multitude of advanced and routine techniques and protocols are used to ensure a comprehensive understanding of the carbon's structure, texture, composition, and physical

and chemical properties, meeting standards set by ASTM International or similar.

The **current results** from the analysis of the carbon samples produced during the lab-scale ColdSpark® methane cracking process show a **very high-purity carbon**, which application may vary. The current market dynamics suggest two primary pathways for carbon utilisation according to Prof. Chavan:

- Industry Applications: The first data received hold promise for applications in the *metal and tire industries*, serving as a sustainable alternative to conventional carbon sources. Industries such as tire manufacturing and metal production require carbon in substantial volumes. The process aims to cater to these sectors, providing a significant market for bulk carbon.
- High-Quality Applications: Sectors like *batteries* and other applications demanding high-quality carbon with high purity, though niche, hold a very high importance. However, the market size for such applications may not be as substantial as bulk industries.

Some other diverse applications of ColdSpark®'s carbon, however, extend beyond traditional sectors adding several diverse applications and additional areas of interest, which should be further investigated:

- Carbon Concrete: Ongoing research explores the incorporation of carbon into cement mixtures, aiming to reduce CO2 emissions in concrete production, a significant contributor to carbon footprints in the construction sector.[1]
- Quantum Dots: The fine, small-sized carbon produced may find applications in many fields including biomedicine, catalysis, optoelectronic devices, and anticounterfeiting, presenting opportunities for application of the carbon received in advanced technologies.

Beyond the initial carbon products, as Prof. Cavan emphasises, there lies an opportunity for **post-processing to change the carbon form**. This opens paths towards the production of specialty carbon, potentially tapping into niche markets and further contributing to economic sustainability.

The environmental implications of ColdSpark®'s technology are noteworthy. The eCarbon® produced by ColdSpark® holding an already registered trademark presents an **eco-friendly alternative** for industries currently reliant on coal, mitigating methane emissions and contributing to a lower $CO_2$ footprint. The production of low $CO_2$ hydrogen aligns with the broader goal of reducing greenhouse gas emissions. This is supplemented by the production of solid carbon which shares the same low $CO_2$ footprint, creating a win-win scenario for both hydrogen and carbon applications.

As the ColdSpark® project progresses and the scientific team optimises the process for large-scale industrial application, challenges and expectations can emerge at every step. While the current focus is on elemental carbon, as Prof. Chavan explains, the optimisation

process may yield variations in carbon quality. Thus, the scalability of the process remains a critical aspect that could influence the final characteristics of the carbon produced.

ColdSpark®'s exploration of carbon exploitation pathways stands at the successful and optimised combination of **innovation, economic viability, and environmental responsibility**. The project's commitment to optimising the hydrogen production process and at the same time ensuring the applications of valuable carbon produced position it as a significant and promising solution in the dynamic development of diverse methods for sustainable energy production.

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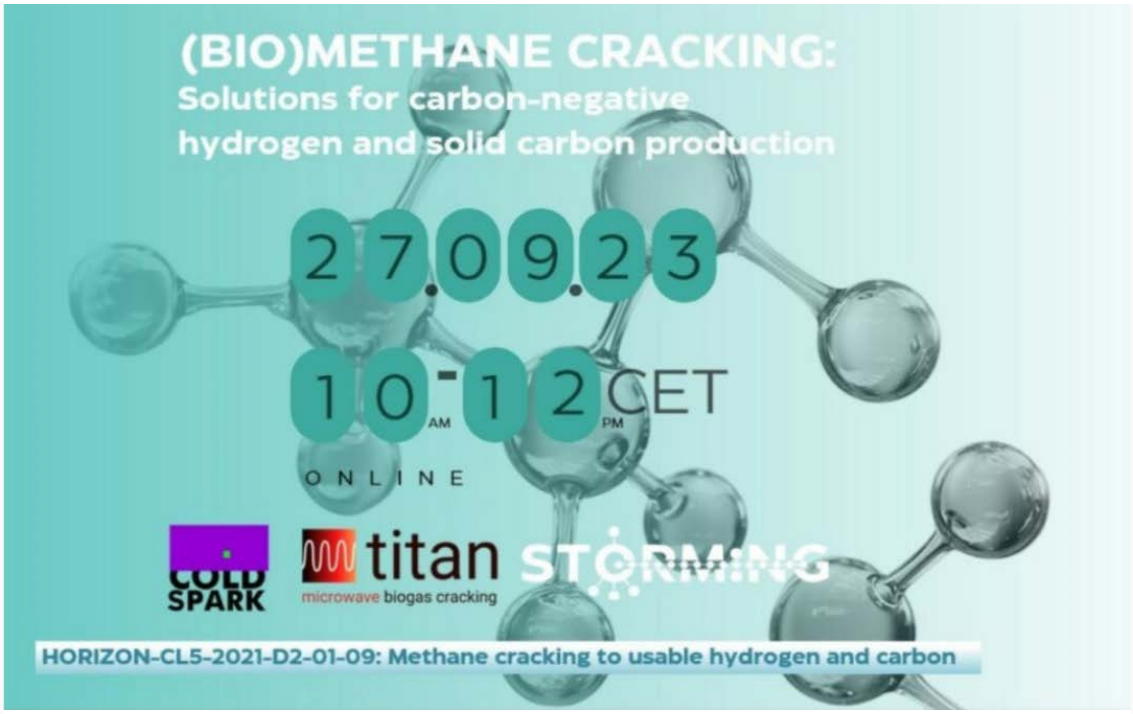
[1] https://theconstructor.org/building/carbon-concrete/565362/

*In ColdSpark®, collaboration, expertise, and continuously attracting highly qualified scientists play a crucial role, especially in addressing challenges related to the collection and isolation of fine carbon particles. We continuously **welcome contributions from experts** in the field to refine the process and enhance the project's overall success so don't hesitate to contact us if you would like to take part in this exciting journey.*

## ColdSpark® synergies




ColdSpark® project looks for opportunities for sharing the advancements in methane cracking technology. In its lifetime, it will collaborate with projects with similar goals, including the ones from the same call:

**STORMING: STructured unconventional reactors for $CO_2$-fRee Methane catalytic crackING** is a ColdSpark® sister project aiming to develop breakthrough and innovative structured reactors heated using renewable electricity. The goal of the project is to convert fossil and renewable $CH_4$ into $CO_2$-free $H_2$ and highly valuable carbon nanomaterials for battery applications.

LEARN MORE ON STORMING'S GOALS AND LATEST DEVELOPMENTS

**TITAN: Direct biogas conversion to green $H_2$ and carbon materials by scalable microwave heaTed catalytIc reacTor for soil Amendment and silicon carbide production**, the other project from the same call, plans to build a scaled fluidized bed reactor to convert biogas into carbon and hydrogen. Project partners anticipate that the reactor will have the capacity to produce 0.6 megatonnes of green hydrogen in 2030.

CHECK HERE TO LEARN MORE ON TITAN

On September 27, 2023, the three EU-funded projects—Coldspark®, STORMING, and TITAN joined in a joint online event. Drawing over 100 industry and academic experts, politicians, and citizens from across Europe, the event presented the revolutionary solutions of the three projects marking a significant stride towards a greener, cleaner energy landscape.

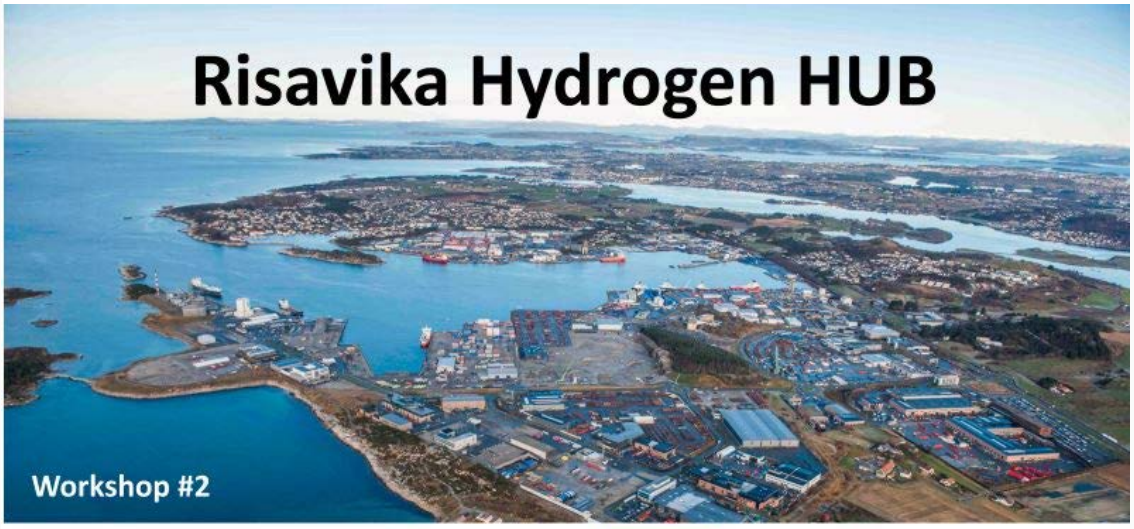
The core focus of the webinar centered around groundbreaking technologies developed by Coldspark®, STORMING, and TITAN. These projects showcased innovative solutions

aimed at transforming methane into valuable hydrogen and solid carbon materials. Such advancements hold immense promise in revolutionizing (bio)methane cracking, charting a course toward carbon-negative hydrogen production.

Another important aspect of the webinar was the scene it provided for a discussion of the policy landscape surrounding (bio)methane cracking. Delving into the intricacies of methane and hydrogen sectors, discussions highlighted existing gaps.

The event fostered collaboration and knowledge exchange among stakeholders. With representatives from project partners, policymakers, industry leaders, and innovators, the discussions created space for engaging synergies, replication potential, and technology uptake in the sector. The webinar highlighted the substantial interest and potential of (bio)methane cracking in driving carbon-negative hydrogen production and solid carbon material utilisation.

## On the way to TRL5:
## a new hydrogen test center in Risavika




The ColdSpark® project continues its progress towards demonstrating the real-world feasibility of its methane-cracking technology. As it completes its lab-scale phase, the project now turns towards the fine-tuning processes for industrial-scale implementation. This path toward commercialization and scaling up marks a crucial milestone for the project, paving the way for future adoption of the technology and exploitation.

An important development in this endeavour is the transformation of the Risavika gas center into a test hub for the development of new value chains centered around eco-friendly hydrogen production. This move represents a significant step towards establishing sustainable energy solutions and fostering innovation in the region.

The tests that will be carried out in Risavika Hydrogen Hub are an integral part of the ColdSpark® project. By utilising the extensive facilities available at Risavika, including access to natural gas, district heating, and electricity supply, the project seeks to prove the feasibility of its solution on a large scale.

The forthcoming relocation of the ColdSpark® project to the Risavika test center will be announced soon.  Stay tuned for further announcements as we continue to progress towards our goals.

For the latest updates and news, please visit our website and follow the ColdSpark LinkedIn page.

## ColdSpark® visibility: events

### Revolutionising hydrogen with ColdSpark® from biomethane workshop

ColdSpark® organised its first event "Revolutionizing hydrogen with ColdSpark® from biomethane" in Liverpool, on June 15th, 2023. The event announced the success of lab-scale tests and illuminated the potential of the ColdSpark® technology set to transform the energy sector.


The workshop commenced with an engaging presentation by Terje Hauan, the project coordinator from SEID AS, who explained the importance of plasma technologies in shaping the energy landscape. He highlighted initial laboratory-scale achievements, emphasising ColdSpark®'s viability compared to traditional water electrolysis methods. Notably, the ColdSpark® technology requires **seven times less energy to crack molecule bonds**, presenting a good reason for the industrialisation of the process and its wide adoption. A video demonstration further showcased the efficiency of the SEID pulsed system in facilitating rapid changes in electricity, rendering the cold methane cracking process feasible.

Throughout the event, project partners elucidated their organisational contributions and roles, emphasizing the collaborative spirit driving ColdSpark®'s development. Crucially, the workshop underscored the pivotal role of investing in the biogas industry as a fundamental

source for producing hydrogen using ColdSpark® technology.

Carbon samples produced at the laboratory scale served as tangible evidence of the project's advancements, setting a promising trajectory as ColdSpark® aims for market availability in the summer of 2024. With container options capable of producing up to 1500 kg of hydrogen per day, ColdSpark® will revolutionize the energy landscape with its innovative, sustainable, and economically viable solution.

## Where to meet us in the upcoming months?

In 2024 ColdSpark® will be presented in a number of events. Some of the most important ones are:

- **Global Methane Initiative Annual Meeting, 18–21 March, Geneva, Switzerland**
- **International Conference & Expo on Biofuels and Bioenergy, 11–12 April, Rome, Italy**
- **IWA World Conference on Anaerobic Digestion**, Istanbul, Turkey
- Emission Reduction 2024 Conference, 3-4 June, Nürtingen, Germany

## ColdSpark® is online

Visit our website and follow us to find more!


Check the project ZENODO account and stay tuned to the latest scientific developments!

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