Hydrogen, which is a by-product of a recycling process, is used in this engine to efficiently generate electricity and heat

Source: AM-Power

Heat and Electricity from Waste Hydrogen – Potential for Various Industries

The development of a global hydrogen economy has been a core issue in international energy policy for years. Although the discussions often revolve around green hydrogen and the development of the necessary generation capacities, there is also great potential in other areas that needs to be exploited. One of these is the use of waste hydrogen from the semiconductor industry to efficiently generate electricity and heat using combined heat and power systems.

In today's highly technical society, semiconductors have become an integral part of everyday life. Whether in computers, smartphones, cars or medical technology – semiconductors are an essential core component in all devices. With a share of more than 60% of the world market, Taiwan is considered the global center of the semiconductor industry, which is why the country is always in the spotlight in times of international conflicts. Regardless of the political discussions, the semiconductor industry faces the same challenges as all industries worldwide. Also in Taiwan, the current focus is often on how issues relating to sustainability and environmental protection can be combined as efficiently as possible with growth and economic viability. Semisils Applied Materials Corporation Ltd. based in Tainan in southwestern Taiwan has set itself the goal of doing exactly that. The company collects the leftovers from semiconductor production from various companies within Taiwan to recycle them and to provide a raw material for other industries.

Circular economy as a core goal

With global environmental and climate protection requirements and an increasing awareness of limited natural resources, the fundamental

call for recyclable materials and the basic mindset of a circular economy in industry is increasing everywhere. The term "Zero Waste Plant" has been on the rise for years and is putting corresponding pressure on companies. Regarding the semiconductor industry, the main question is: How can residual materials be recycled or processed for other areas? One of the most important wastes in semiconductor production is silicon. Among other things, this occurs when raw, round chips are shaped into rectangular shapes. In the past, the waste material from cutting and punching was frequently incinerated without being repurposed or utilised further. This is exactly where Semisils' business model comes into play.

Semisils is the first company in the world to have succeeded in developing a process in which the remaining silicon residue can be recycled – a quantum leap in circular economy. In the patented and secret process, the "silicon sludge", a mixture of silicon and water, is processed so that the resulting materials can subsequently be reused as a raw material in various industries. Examples include the production of epoxy and chemical raw materials to produce safety shoes. One of the by-products of this recycling process is hydrogen, whose efficient use will now further optimise the overall process and could even be groundbreaking for other industrial processes around the world.

Use of hydrogen for energy supply

Since its founding in 2013 and the associated start of silicon recycling, Semisils has been asking itself how hydrogen could be used as sensibly within the company as possible – especially regarding its own energy supply. In order to promote the use of hydrogen as intensively as possible, Taiwan Green Hydrogen Corporation was founded as a 100% subsidiary of Semisils. In terms of technology, they initially relied on a PEM fuel cell, which is already widely used in many other applications, particularly in Asia. However, after a short time it became apparent that the hydrogen obtained in the recycling process, with a purity level of between 98 and 99%, was too impure for the fuel cell to operate continuously. In addition, many tests made it clear that the PEM fuel cell struggled with a significant loss of electrical efficiency over a period of several months, so that the application was not long-term effective.

The use of hydrogen for its own energy supply was initially shelved again – until 2021. In this year, Semisils encountered AM-Power Inc., which specialises in decentralised energy solutions for industrial applications, among other things. A core concept: The use of combined heat and power (CHP) plants to efficiently generate electricity and heat with molecule-based fuels. When the two companies met, the idea of converting hydrogen into usable electrical or thermal energy with a gas engine instead of a fuel cell came into play for the first time. AM-Power sales specialist Andrew Lee (Figure 1) remembers: "When we first met Semisils and Taiwan Green Hydrogen Corporation, the local decision-makers were not aware that a gas engine could be the solution to the puzzle. Fuel cell applications have a long history, especially in Asia, such as in the automotive sector, so the gas engine was not on the agenda until now."

What proved pivotal at this juncture was AM-Power's collaboration with the German manufacturer of CHP systems, 2G Energy. By 2018, 2G Energy had already initiated series production for hydrogen-powered CHP plants and has since executed over 30 projects worldwide. The manufacturer, which originally comes from the biogas sector, has been involved in the efficient con-

Figure 1. Andrew Lee of AM-Power has managed the installation of the project on site

Source: AM-Power

Figure 2. The well-established 2G control system allows a continuous and reliable hydrogen CHP operation Source: AM-Power

version of gases from various sources into electricity and heat since the company was founded in 1995. Based on this history, 2G was willing to take on the implementation of the project in Taiwan, explains CTO Frank Grewe: "The successful development of engine technology and the use of different types of gas has always guaranteed growth for the company in the last few decades. We have consistently prioritised our development efforts precisely in areas where new market opportunities have emerged. Whether it was the swiftly expanding biogas market in Central Europe and Japan in the early 2000s or the adoption of CHP systems in sewage treatment plants, we have consistently focused our development efforts on burgeoning market trends. Adapting the engine to the type of gas specification is certainly something like the DNA of our company."

The focus on hydrogen as a result of the global discussions is only logical, Grewe continues: "As a manufacturer of CHP systems, it is almost mandatory that we deal with the topic of hydrogen. Looking back, we are happy that we have started our development almost 15 years ago and have now reached series production. Projects like those in Taiwan are an excellent way to gradually transfer development into commercial practice. Above all, these types of projects ensure great motivation within your own workforce, as they align with contemporary development trends."

Technological advantages of motor-driven CHP systems when using waste hydrogen

As already explained, the first attempts to use hydrogen only for energy purposes were based on the use of fuel cells, which had problems with the lack of purity of the hydrogen during operation. Due to contamination of the membrane, the performance was significantly reduced after a short time and repeatedly led to the system failing. In comparison, the problem does not arise with a hydrogen engine and its basic technical concept of direct injection into the combustion chamber. 2G chief developer Grewe points to the robustness of the engines: "Our origins are rooted in the biogas industry, which, particularly in its early stages, was not typically associated with pure gases. Accordingly, our development work has always been characterised by the handling of impure gases and engine adaptation as well as the provision of suitable peripheral components."

But Grewe also emphasises once again that the use of hydrogen – whether pure or impure – poses no technical impediment to engine technology: "Even if hydrogen has its technical challenges – from lower energy density to faster ignitability – in the end it is only one molecule among many that can be used in the engine with the appropriate development work."

Installation on site within a few days due to a standardised concept

In addition to the problem, the overall package offered by AM-Power and 2G was also convincing due to another point: the turnkey delivery in a tailor-made container. Both the engine and the hydraulics as well as the complete control unit (Figure 2) are housed together in one container (Figure 3), so that the set-up and installation on site in July 2023 could be completed within a very short time. This was a huge advantage, especially for the customer, explains Lee: "The on-site installation took just 1.5 weeks, minimising disruption to on-site operations and keeping costs for all involved parties exceptionally low."

This approach was made possible above all by the standardisation concept, which 2G has been pushing forward in its plant construction for many years. Grewe underlines the internationalisation strategy that 2G wants to promote in a targeted manner: "Developing hydrogen engines is one thing – but also integrating them optimally into the operator's infrastructural requirements is another. Our standardised container solutions make it possible to implement such projects at all."

The CHP system's operation was initially designed for full-load operation, in which approx. 10-20% of

Figure 3. Both the engine and the hydraulics as well as the complete control unit were delivered in a tailor-made container Source: AM-Power

the electrical energy generated is consumed directly and the rest of the electricity is fed into the public supply network. The heat generated can in turn be optimally used in the production halls for the recycling process. After almost a year of running the system, Lee is more than thrilled: "Admittedly, we were all surprised at how well the project went from the first minute." The next projects including hydrogen CHP are already being planned.

The project is just a first glimpse of the existing potential

The project has established new benchmarks in both hydrogen production and its utilisation as energy, showcasing the immense potential for gas engines in the future. "There are many other areas such as the chemical or fertiliser industries that also looking into tap into hydrogen economy where they are either looking to utilise waste hydrogen or produce green hydrogen on their own. Especially in current times when the demand for hydrogen is increasing but the corresponding quantities are lacking, the concept we have developed offers a solution that could solve challenges in numerous places worldwide." In this context, Lee takes a look at the future of photovoltaic (PV) industry: "We are all pleased about the massive increase in the installation of new PV systems and electric cars. However, this area will also generate a lot of silicon scrap in the next few decades that needs to be recycled. Our project could create a blueprint for how to reconcile circular economy and security of supply with electricity and heat."

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