Press Kit

Content

Press Contact

Fraunhofer Institute for Ceramic Technologies and Systems IKTS:

Katrin Schwarz
Head of Press and Public Relations
Phone: +49 351 2553-7720
E-Mail: pk@ikts.fraunhofer.de

Annika Ballin
Press and Public Relations
Phone: +49 351 2553-7231
E-Mail: pk@ikts.fraunhofer.de

thyssenkrupp nucera:

Katharina Immoor
Head of Communications & ESG
Phone: +49 231 547 2863
E-Mail: katharina.immoor@thyssenkrupp.com

Dr. Adrian Schaffranietz
Head of External and Internal Communications
Mobile: +49 152 2470 3595
E-Mail: adrian.schaffranietz@thyssenkrupp-nucera.com

Rita Syre
Senior Media Relations Manager
Mobile: + 49 174 161 86 24
E-Mail: rita.syre@thyssenkrupp-nucera.com

Dr. Marcel Kleifeld
Senior External Communications Manager
Phone: +49 231 229 724 347
E-Mail: marcel.kleifeld@thyssenkrupp-nucera.com

thyssenkrupp nucera AG & Co. KGaA, Freie-Vogel-Str. 385 a, 44269 Dortmund
T: +49 231 547-7100, F: +49 231 547-2334,
Handelsregister: Amtsgericht Dortmund, HRB 33774
Vorsitzender des Aufsichtsrats: Dr. Volkmar Dinstuhl

Persönlich haftende Gesellschafterin: thyssenkrupp nucera Management AG
Handelsregister: Amtsgericht Dortmund, HRB 33591
Vorstand: Dr. Werner Ponikwar, Dr. Stefan Hahn
Vorsitzender des Aufsichtsrats: Dr. Volkmar Dinstuhl

Fraunhofer-Institut für Keramische Technologie und Systeme IKTS, Winterbergstraße 28, 01277 Dresden
P +49 351 2553-7231 | www.ikts.fraunhofer.de | presse@ikts.fraunhofer.de
Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V., München
Vorstand: Prof. Dr.-Ing. Holger Hanselka, Präsident;
Ass. jur. Elisabeth Ewen; Dr. rer. pol. Sandra Krey;
Prof. Dr. rer. nat.habil. Axel Müller-Groeling

Press Release

thyssenkrupp nucera and Fraunhofer IKTS open First SOEC Pilot Production Plant for Stacks for the Production of Green Hydrogen

- **Important milestone on the road to commercial and large-scale industrial use of highly innovative SOEC electrolysis for decarbonizing industry**
- **Significant cost advantage in certain areas of application thanks to high efficiency of high-temperature electrolysis technology (SOEC)**
- **Strengthening of thyssenkrupp nucera's hydrogen technology portfolio for industrial applications with SOEC as the perfect complement to existing AWE technology**

Arnstadt/Dortmund, May 27, 2025 – thyssenkrupp nucera and Fraunhofer IKTS opened the first SOEC pilot production plant for electrolysis stacks on May 27 in Arnstadt, Thuringia, in the presence of high-ranking representatives from science, politics, and industry. The event was also attended by the Minister President of the State of Thuringia, Prof. Dr. Mario Voigt. With the commissioning of the pilot production plant, the strategic partnership between Fraunhofer IKTS and thyssenkrupp nucera for the development of high-temperature electrolysis (SOEC) is entering the next phase as planned.

In March 2024, the renowned research institute and the world's leading supplier of highly efficient electrolysis technology for the production of green hydrogen in Arnstadt signed a strategic cooperation agreement for the development of the next-generation SOEC electrolyzer. Building on the development work carried out by Fraunhofer IKTS, thyssenkrupp nucera will now work with Fraunhofer IKTS to advance SOEC technology for the manufacture of stacks for the production of green hydrogen on an industrial scale. With high-temperature electrolysis, thyssenkrupp nucera is strengthening its hydrogen technology portfolio for industrial applications.

The electrolysis stacks are manufactured in the pilot production plant designed and built by Fraunhofer IKTS. The SOEC pilot plant initially produces stacks in small quantities and has a target production capacity of 8 megawatts per year. These stacks are the heart of the future SOEC electrolyzers from thyssenkrupp nucera.

SOEC stack technology is based on an oxygen-conducting ceramic electrolyte substrate with two electrodes, which are assembled together with coupling elements, the chromium-iron (CF) interconnectors, on several layers to form the stack. CF-based SOEC technology guarantees high

thyssenkrupp nucera AG & Co. KGaA, Freie-Vogel-Str. 385 a, 44269 Dortmund
T: +49 231 547-7100, F: +49 231 547-2334,
Handelsregister: Amtsgericht Dortmund, HRB 33774
Vorsitzender des Aufsichtsrats: Dr. Volkmar Dinstuhl

Persönlich haftende Gesellschafterin: thyssenkrupp nucera Management AG
Handelsregister: Amtsgericht Dortmund, HRB 33591
Vorstand: Dr. Werner Ponikwar, Dr. Stefan Hahn
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Fraunhofer-Institut für Keramische Technologie
und Systeme IKTS, Winterbergstraße 28, 01277 Dresden
P +49 351 2553-7231 | www.ikts.fraunhofer.de |
presse@ikts.fraunhofer.de
Fraunhofer-Gesellschaft zur Förderung der angewandten
Forschung e. V., München
Vorstand: Prof. Dr.-Ing. Holger Hanselka, Präsident;
Ass. jur. Elisabeth Ewen; Dr. rer. pol. Sandra Krey;
Prof. Dr. rer. nat. habil. Axel Müller-Groeling

corrosion resistance, optimized thermal cycle performance, and high long-term stability with regard to temperature cycling. In addition, stack technology requires only a small number of components and occupies a leading position compared to designs currently available on the global market. The SOEC cell design is also well suited for the desired highly automated series production. Thanks to the large-scale industrial and highly automated series production planned for the future, the high-temperature electrolyzer can also be manufactured at competitive costs.

With innovative high-temperature electrolysis, companies will be able to produce green hydrogen highly efficiently in the future. SOEC electrolysis ensures high efficiency because less electrical energy is required to split water vapor at high temperatures. When commercial high-temperature electrolysis is used in processes that generate large amounts of waste heat, such as in the steel industry, electricity consumption can be reduced by 20% to 30% compared to other technologies.

In addition, SOEC technology offers the major advantage of utilizing industrial CO2 as a raw material and converting it into green synthesis gas together with green hydrogen. This in turn can be used to produce sustainable chemical feedstocks and e-fuels—a unique selling point with enormous potential for the energy transition.

"The outstanding properties of SOEC technology have prompted us to work with our strategic partner Fraunhofer IKTS to develop high-temperature electrolysis to market maturity. We are convinced of the advantages of this electrolysis technology for the production of green hydrogen. It will play a central role in a new, climate-friendly energy mix," says Dr. Werner Ponikwar, CEO of thyssenkrupp nucera.

“By integrating SOEC technology into industrial waste heat sources or directly generating synthesis gas from water and CO_2, companies can maximize the efficiency of green hydrogen production and effectively implement their decarbonization strategy. These unique advantages make SOEC technology a real game changer,” says Professor Alexander Michaelis, Director of Fraunhofer IKTS.

The operation of the pilot production plant will generate the necessary experience that will be incorporated into the construction of a fully automated, large-scale industrial SOEC production plant for high-performance stacks.

Photos:
If you need photos, please contact us.

Media inquiries:

Fraunhofer-Institut für Keramische Technologien und Systeme IKTS
Annika Ballin
Press and Public Relations
Phone: +49 351 2553-7231

E-Mail: annika.ballin@ikts.fraunhofer.de

thyssenkrupp nucera
Rita Syre
Senior Manager Media Relations and Financial Communications
Mobil: +49 174 161 86 24
E-Mail: rita.syre@thyssenkrupp-nucera.com

Investor inquiries:
thyssenkrupp nucera
Dr. Hendrik Finger
Head of Investor Relations
Phone: +49 231 229 724 347
E-Mail: hendrik.finger@thyssenkrupp-nucera.com

About Fraunhofer IKTS:

The Fraunhofer Institute for Ceramic Technologies and Systems IKTS develops high-performance ceramic materials, industry-relevant manufacturing processes, and prototype components and systems in complete production lines up to pilot scale. The portfolio is complemented by expertise in materials diagnostics and testing. The focus is on sustainable and economical solutions for the energy transition, resource conservation, and digitalization. In the field of high-temperature electrolysis, Fraunhofer IKTS has developed various stack designs, builds prototypes, and tests their suitability for different applications and load profiles, including techno-economic evaluation. With currently around 800 employees at 14 locations, Fraunhofer IKTS is the largest ceramics research institute in Europe.
www.ikts.fraunhofer.de

About thyssenkrupp nucera:

thyssenkrupp nucera offers world-leading technologies for high-efficiency electrolysis plants. The company has extensive in-depth knowledge in the engineering, procurement, and construction of electrochemical plants and a strong track record of more than 600 projects with a total rating of over 10 gigawatts already successfully installed. With its water electrolysis technology to produce green hydrogen, the company offers an innovative solution on an industrial scale for green value chains and an industry fueled by clean energy – a major step towards a climate-neutrality. thyssenkrupp nucera successfully made an IPO in July 2023. The company is a member of the SDAX of the Frankfurt Stock Exchange.
www.thyssenkrupp-nucera.com

Facts & Figures

About Fraunhofer Institute for Ceramic Technologies and Systems IKTS

- Das Fraunhofer IKTS develops modern high-performance ceramic materials, industry-relevant manufacturing processes and prototype components and systems in complete production lines up to pilot scale. The portfolio is complemented by expertise in materials diagnostics and testing as well as socio-economic technology assessment and sustainability analysis.
- With 813 employees at 14 different locations and an annual budget of € 96.7 million in 2024 (as of 31.12.2024), Fraunhofer IKTS is the largest ceramics research institute in Europe.
- As a research and technology service provider, Fraunhofer IKTS demonstrates the potential of ceramic materials in a variety of application areas - market-oriented and supplemented by strategic preliminary research.
- The focus is on holistic, sustainable and economical solutions for the energy transition, resource conservation and digitalization.
- Fraunhofer IKTS has more than 30 years of experience in the development and construction of electrochemical reactors for the production and use of hydrogen and has extensive expertise along the entire value chain: from material to system, including economic feasibility studies.
- Successful companies have emerged from the institute's developments.
- In the field of high-temperature electrolysis (SOEC), Fraunhofer IKTS has developed various stack designs, builds prototypes and tests their suitability for different applications and load profiles, including techno-economic evaluation.
- Industrial electrolysis is one of the most important fields of activity. At Fraunhofer IKTS, SOE stacks and modules for integration into electrolysis plants are produced on a pilot scale and optimized in terms of their long-term stability and performance. The focus is now on the development and testing of automated stack production suitable for industrial use as well as modularization concepts for stacks in higher performance classes.
- www.ikts.fraunhofer.de
- Social Media: LinkedIn, Instagram, YouTube

About thyssenkrupp nucera AG & Co. KGaA, Dortmund (Germany)

- thyssenkrupp nucera offers world-leading technologies for highly efficient electrolysis plants. The company has extensive expertise in the planning, procurement and construction of electrochemical plants.
- Its track record includes more than 600 successfully installed projects with a total capacity of more than 10 gigawatts.
- thyssenkrupp nucera is currently working on orders with a total electrolysis capacity of more than 3 gigawatts.
- The company currently has two technologies at its disposal: alkaline water electrolysis and chlor-alkali electrolysis.
- With its water electrolysis technology for the production of green hydrogen, thyssenkrupp nucera is creating innovative solutions on an industrial scale for green value chains and a decarbonized industry - a major step towards climate neutrality.
- Customers include companies such as NEOM in Saudi Arabia, H2 Green Steel in Sweden, Shell in the Netherlands, and more.
- thyssenkrupp nucera successfully completed an IPO in July 2023.
- The electrolysis specialist generated sales of EUR 862 million in the past financial year 2023/2024 (corresponding prior-year period: EUR 661 million). The net result amounted to EUR 11 (24) million. The number of employees rose to 1.012 (previous year: 675) by the end of the financial year (September 30, 2024).
- www.thyssenkrupp-nucera.com
- Social Media: LinkedIn thyssenkrupp nucera | LinkedIn

The Management of thyssenkrupp nucera

Dr. Werner Ponikwar

CEO thyssenkrupp nucera AG & Co. KGaA (as Executive Board member of the General Partner thyssenkrupp Management AG)

Professional background:

Holding a Ph.D. in Chemistry from the LMU Munich, Dr. Werner Ponikwar has gained 20+ years of experience in the chemical industry. He held leading positions including business development, corporate strategy and management at German stock-listed companies such as Evonik Degussa and Linde.

In his last role, he served as CEO of Linde Hydrogen FuelTech, a global technology provider of hydrogen refuelling stations, focused on the full product life cycle, incl. the development, manufacturing, sales, erection and service. As the new CEO of thyssenkrupp nucera, he will drive the development of the business to a standalone company to become a global hydrogen technology champion. As the CEO of thyssenkrupp nucera, Dr. Werner Ponikwar is responsible for sizing the business in all regions with a clear vision and growth strategy.

Dr. Stefan Hahn

CFO thyssenkrupp nucera AG & Co. KGaA (as member of the board of directors of the general partner thyssenkrupp Management AG)

Professional background:

Dr. Hahn started his career at the thyssenkrupp Group in 2012 in Mergers & Acquisitions. He worked in senior management positions in the field of Controlling, Accounting & Risk for various companies in the thyssenkrupp Group, including thyssenkrupp AG, thyssenkrupp Bilstein und thyssenkrupp Decarbon Technologies.

Before taking up his current position, he held CFO positions at thyssenkrupp Automation Engineering and thyssenkrupp Polysius. Dr. Hahn graduated with a PhD from the WHU – Otto Beisheim School of Management, Vallendar.

Dr. Hahn has been CFO since March 2025 and is responsible for the Corporate Functions Commercial Operations/Tax, Controlling, Accounting & Risk, Finance, Information Technology, Investor Relations, Project Execution/Procurement, Project Risk Control & QM. In addition, Dr. Hahn is responsible for the business activities of the subsidiaries in Australia, India and Saudi Arabia.

Klaus Ohlig
Designated CTO (as of July 1, 2025)

Professional background:
Klaus Ohlig distinguished career includes senior leadership roles at Linde, notably as Executive Director Research & Development at Linde Engineering in Pullach, where he managed global teams and was responsible for the development and expansion of Linde Engineering's technology portfolio. Before that, he was Managing Director of Linde Kryotechnik AG in Switzerland.

Management of Fraunhofer Institute for Ceramic Technologies and Systems IKTS

Prof. Dr. rer. nat. habil. Alexander Michaelis
Institute Director of Fraunhofer IKTS and Professor of Inorganic Non-Metallic Materials at TU Dresden

Prof. Alexander Michaelis studied physics at the University of Düsseldorf and completed his doctorate in materials science there. He has more than 30 years of professional experience in ceramics, energy and environmental technology. After holding positions at the University of North Carolina (USA), Siemens AG (USA) and Bayer AG, he became head of the "Development of New Business Areas" department at Bayer subsidiary H.C. Starck GmbH. Prof. Michaelis has been Professor of Inorganic Non-Metallic Materials at the Technical University of Dresden since 2002.He has been Institute Director of Fraunhofer IKTS since 2004. He holds 42 patent families and has received numerous awards, including the ACerS Bridge Building Award, the "Medal of Leadership" of the American Ceramic Society, the Fraunhofer Medal and the LEE HSUN Award on Materials Science of the Chinese Academy. Prof. Michaelis is an academy member of the World Academy of Ceramics WAC, a fellow of the American Ceramic Society (ACerS) and the European Ceramic Society. From 2019 to 2023, he was President of the German Ceramic Society (DKG e. V.) and is still Chairman of the DKG Research Association (FDKG).

Dr. rer nat. Roland Weidl
Deputy Institute Director Fraunhofer IKTS,
Site Manager Arnstadt.

Dr. Roland Weidl studied physics at the Justus Liebig University in Giessen and obtained his doctorate in solid state physics at the Friedrich Schiller University in Jena. He has almost 30 years of professional experience in energy research and technology development. After his research activities at INNOVENT Technologieentwicklung e. V. Jena, he moved to SCHOTT Solar Thin Film GmbH, where he was responsible for product management. From 2014 to 2023, Dr. Weidl headed the „System Integration and Technology Transfer" department at Fraunhofer IKTS with the research areas of fuel cell systems and high-temperature batteries. Since 2020, Dr. Roland Weidl has been site manager of Fraunhofer IKTS in Arnstadt with the Battery Innovation and Technology Center BITC and the "WaTTh - Industrial Hydrogen Technologies Thuringia". In 2023, he was appointed Deputy Director of the institute. He received the

Thuringian Research Award for Applied Research in 2019 and has already received the Fraunhofer Prize "Best Customer Acquisition of the Year" on three occasions (2019, 2022, 2024).

Prof. Dr. rer nat. Michael Stelter

Deputy Institute Director of Fraunhofer IKTS and Professor of Technical Environmental Chemistry at Friedrich Schiller University Jena.

Prof. Michael Stelter studied Physical Chemistry and Electrochemistry as well as Technology Assessment at Chemnitz University of Technology, where he also obtained his doctorate. He has more than 20 years of professional experience in energy and environmental technology. He worked in a leading position at Sachsenring AG in the field of "Advanced Development Vehicle Systems" and at Webasto AG in the field of "Fuel Cell Systems/Functional Ceramics".

He has held various positions at Fraunhofer IKTS since 2005 and has been Deputy Institute Director with a focus on marketing and strategy since 2013. He is Director at the Center for Energy and Environmental Chemistry (CEEC) at Friedrich Schiller University Jena, a board member of the Thuringian Renewable Energy Network (ThEEN) e. V. and spokesman for the Thuringian Water Innovation Cluster ThWIC.

Prof. Dr. rer nat. Ingolf Voigt
Deputy Institute Director Fraunhofer IKTS,
Site Manager Hermsdorf

Prof. Ingolf Voigt studied chemistry at the Friedrich Schiller University in Jena and received his doctorate in solid state chemistry. He has more than 30 years of experience in ceramics and environmental technology. From 1993, he worked at the Hermsdorf Institute for Technical Ceramics HITK, first as a scientist, then as group and division manager and later as Deputy Institute Director. After the integration of HITK into Fraunhofer IKTS, he took over the management of the "Environmental Technology and Bioenergy" department from 2010 to 2013 and has been part of the institute management and head of the Hermsdorf site since 2013. With a focus on ceramic technology and membrane technology, he is a lecturer at Friedrich Schiller University and Ernst Abbe University Jena.

The latter awarded him an honorary professorship in 2018. Prof. Voigt has received several awards, including the Thuringian Research Prize, the Joseph von Fraunhofer Prize and the Corporate Environmental Achievement Award from the American Ceramic Society. In addition to numerous other committee activities, Prof. Voigt is a board member of Tridelta Campus Hermsdorf e. V. and is committed to the development and networking of industry and research in Eastern Thuringia.

Dr.-Ing. Christian Wunderlich
Deputy Institute Director Fraunhofer IKTS,
Site Manager Dresden-Klotzsche

Dr. Christian Wunderlich studied and completed his doctorate at the TU Chemnitz in the field of mechanical engineering. He has more than 25 years of professional experience in R&D management. He worked in management positions at SKF GmbH Application Technology, Sachsenring AG Zwickau and Alstom Ballard GmbH in Canada before becoming responsible for APU development at Webasto AG in 2002. In 2003, he initiated a cooperation project between the partners Webasto, H.C. Starck and Fraunhofer IKTS for the commercialization of SOFC stacks.

In 2005, staxera GmbH was founded as a joint venture – the first supplier of integrated SOFC stacks and stack modules. From 2005 to 2011, Dr. Wunderlich led the company as CEO before it was sold to Sunfire GmbH in 2011. Since 2011, Dr. Wunderlich has been working at Fraunhofer IKTS, initially as head of the department “System Integration and Technology Transfer”. Since 2014, he has been Deputy Institute Director and Site Director at Fraunhofer IKTS Dresden-Klotzsche. He heads the business units Nondestructive Testing and Monitoring as well as Mechanical and Automotive Engineering.

Dr.-Ing. Michael Zins
Deputy Institute Director Fraunhofer IKTS,
Administrative Director

Dr. Michael Zins studied mechanical engineering at RWTH Aachen University, where he completed his doctorate at the Institute for Ceramic Components in the field of mechanical engineering. He has many years of experience in ceramic technology and is well connected in the ceramics industry. From 1993 to 2015, he was Managing Director and Managing Partner of Technologie Agentur Struktur Keramik TASK GmbH in Aachen and Dresden. At the same time, he took over the management of the Structural Ceramics research division at Fraunhofer IKTS with four departments in 2002. He has been Deputy Institute Director and Administrative Director since 2006. For many years, he headed the Fraunhofer-Gesellschaft's AdvanCer Alliance for Advanced Ceramics as well as other strategic project initiatives. As Administrative Director of Fraunhofer IKTS, which consists of several departments, he is responsible for strategic organizational development as well as organizational and contractual issues.

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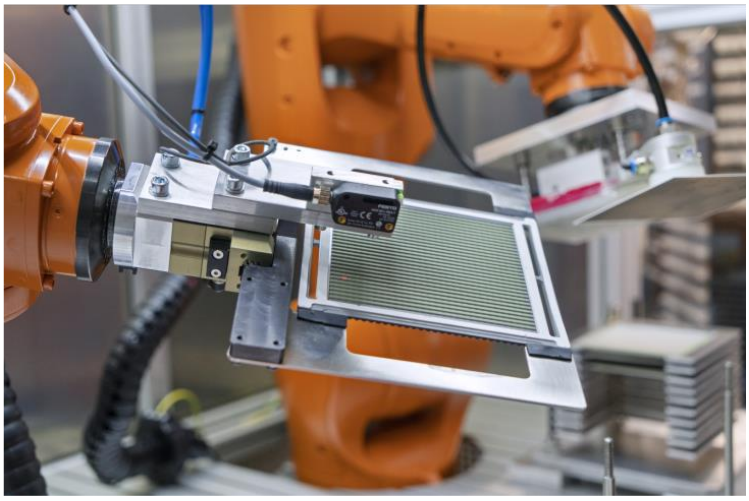
Electrolysis technologies at a glance

- **Alkaline water electrolysis** (AWE) is a process for producing hydrogen from water using electricity. If electricity from renewable energy sources is used, it is green hydrogen.
- **Chlor-alkali electrolysis** is a process for producing the important basic chemicals chlorine, hydrogen and caustic soda from sodium chloride and water.
- **PEM electrolysis** (Proton Exchange Membrane) is a water electrolysis process. In contrast to alkaline electrolysis, it is carried out in an acidic medium.
- In high-temperature solid oxide electrolysis (**SOEC**), is a water electrolysis process that uses a ceramic solid electrolyte as a conductive membrane and operates at temperatures of 600°C to 900°C. The SOEC can also make climate-damaging CO2 usable for the production of synthesis gas and e-fuels.
- **AEM electrolysis** (anion exchange membrane electrolysis) is a combination of the PEM (proton exchange membrane) and AEL (alkaline electrolysis) electrolysis processes.
- For further information see Glossar - thyssenkrupp nucera (thyssenkrupp-nucera.com) and Electrolysis – Fraunhofer IKTS



Fully automated assembly of individual components into high-temperature electrolyzers (SOC) and high-temperature fuel cells (SOFC). (© Fraunhofer IKTS)

SOEC Technology at a Glance

What does SOEC stand for?

SOEC is the abbreviation for Solid Oxide Electrolysis Cell. SOEC technology refers to high-temperature electrolysis with solid oxide cells.

What is high-temperature electrolysis used for?

High-temperature electrolysis is a process for producing hydrogen from water vapor. If electricity from renewable energies is used for this, it is referred to as green hydrogen.

What happens during high-temperature electrolysis?

In high-temperature electrolysis, water vapor is split into hydrogen and oxygen by applying a voltage. The conversion process takes place at temperatures of 600 °C to 900 °C. The central components are the solid oxide electrolysis cells mentioned above, which are stacked to form a SOEC stack.

thyssenkrupp nucera AG & Co. KGaA, Freie-Vogel-Str. 385 a, 44269 Dortmund
T: +49 231 547-7100, F: +49 231 547-2334, www.thyssenkrupp-nucera.com
Handelsregister: Amtsgericht Dortmund, HRB 33774
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Fraunhofer-Institut für Keramische Technologie
und Systeme IKTS, Winterbergstraße 28, 01277 Dresden
P +49 351 2553-7231 | www.ikts.fraunhofer.de |
pk@ikts.fraunhofer.de
Fraunhofer-Gesellschaft zur Förderung der angewandten
Forschung e. V., München
Vorstand: Prof. Dr.-Ing. Holger Hanselka, Präsident;
Prof. Dr. rer. nat. Constantin Häfner, Prof. Dr. rer. nat. habil. Axel
Müller-Groeling, Elisabeth Ewen, Dr. rer. pol. Sandra Krey

What is distinctive about the SOEC stack technology of Fraunhofer IKTS?
The SOEC stack technology is based on the oxygen-conducting ceramic electrolyte substrate with two electrodes, paired with chromium-based CFY interconnectors. The electrolyte-supported concept therefore guarantees high long-term stability with regard to high-temperature corrosion and thermal cycling. The stack technology is based on a small number of components and occupies a leading position compared to currently available designs on the global market.

How many cells are installed in a SOEC electrolysis stack?
Depending on the required output, up to 40 electrolysis cells are installed in a SOEC electrolysis stack.

What electrolysis outputs are possible with SOEC technology?
The output of high-temperature electrolyzers ranges from the kW to the high MW range.

What are the advantages of high-temperature electrolysis?
High-temperature electrolysis ensures high efficiency, as less electrical energy is required to split the water vapor due to operation at high temperatures. If high-temperature electrolysis is implemented in processes where large amounts of waste heat are available – such as in the steel industry – the consumption of electrical energy can be reduced by 20 % to 30 % compared to other technologies.

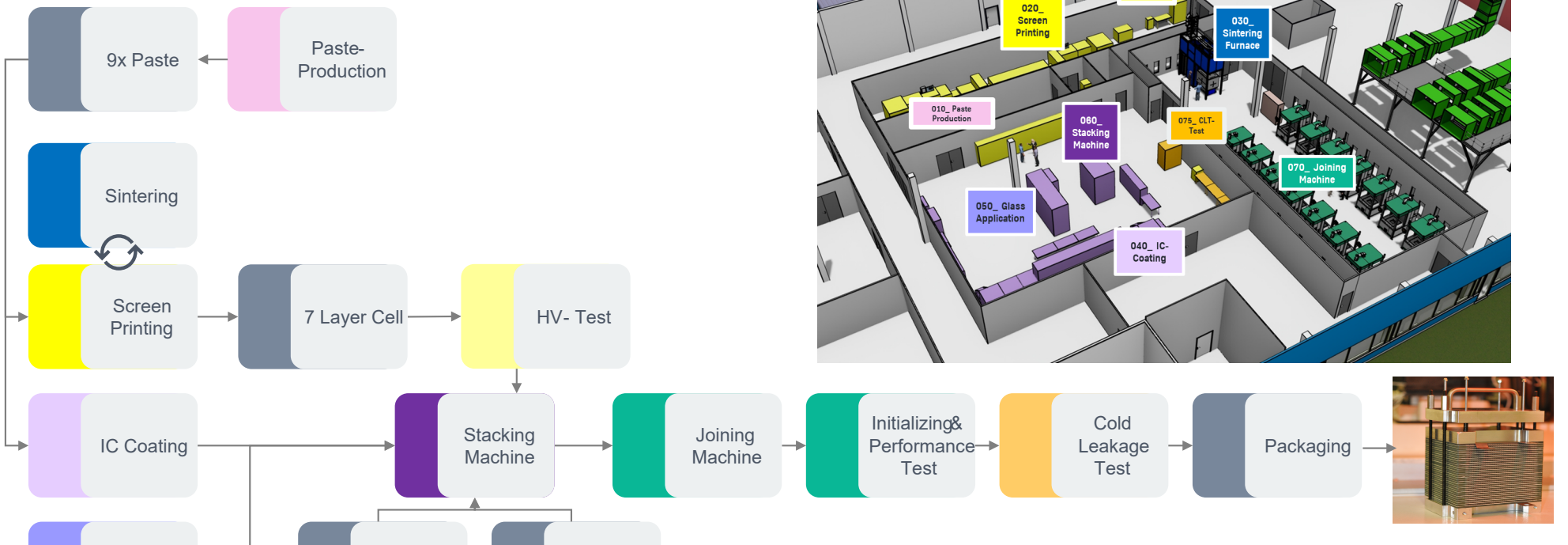
Are there other advantages in addition to the high efficiency?
SOEC electrolyzers can also run in co-electrolysis mode. To do this, water and CO2 are split into oxygen, hydrogen and carbon monoxide. This produces a synthesis gas from the electrical energy, which can be used for the sustainable production of chemical products and e-fuels via Fischer-Tropsch synthesis.

Contact:

Fraunhofer Institute for Ceramic Technologies and Systems IKTS:
Katrin Schwarz
Press and Public Relations
Phone: +49 351 2553-7720
E-Mail: pk@ikts.fraunhofer.de

thyssenkrupp nucera:
Katharina Immoor
Head of Communications & ESG
Phone: +49 231 547 2863
E-Mail: katharina.immoor@thyssenkrupp.com

SOEC pilot production plant: From the paste to the stack



Screen printing

for SOEC- Membrane Electrode Assembly (MEA)

- Precision coating of electrolyte materials, clean room integration
- Inline process control – real-time monitoring of parameters

Sintering

- High-temperature process control during the sintering process
- Homogeneous bond between electrolyte and electrodes for reliable electrochemical performance in SOEC operation

Coating process

for bipolar plates

- Application of uniform, functional layers in the micrometer range
- Inline-process control – real-time monitoring of parameters

High precision punching

- Micrometer-precise contour punching of the glass tape for adaptation to complex cell or stack geometries

Stacking

- Micrometer-precise positioning of the components with an industrial robot
- Camera-based detection and adjustment of each position

Joining

- Joining of single cells to a gas-tight stack
- Use of process gases to avoid oxidation and for targeted electrochemical initialization
- Precise, even force distribution over the overall stack-cross-section
- Performance testing after the joining process in reversible fuel cell operation (SOFC), to validate the tightness, electrical contact, and reactivity of the stack

Expansion stage 2:

Paste production

- Production of 9 different pastes

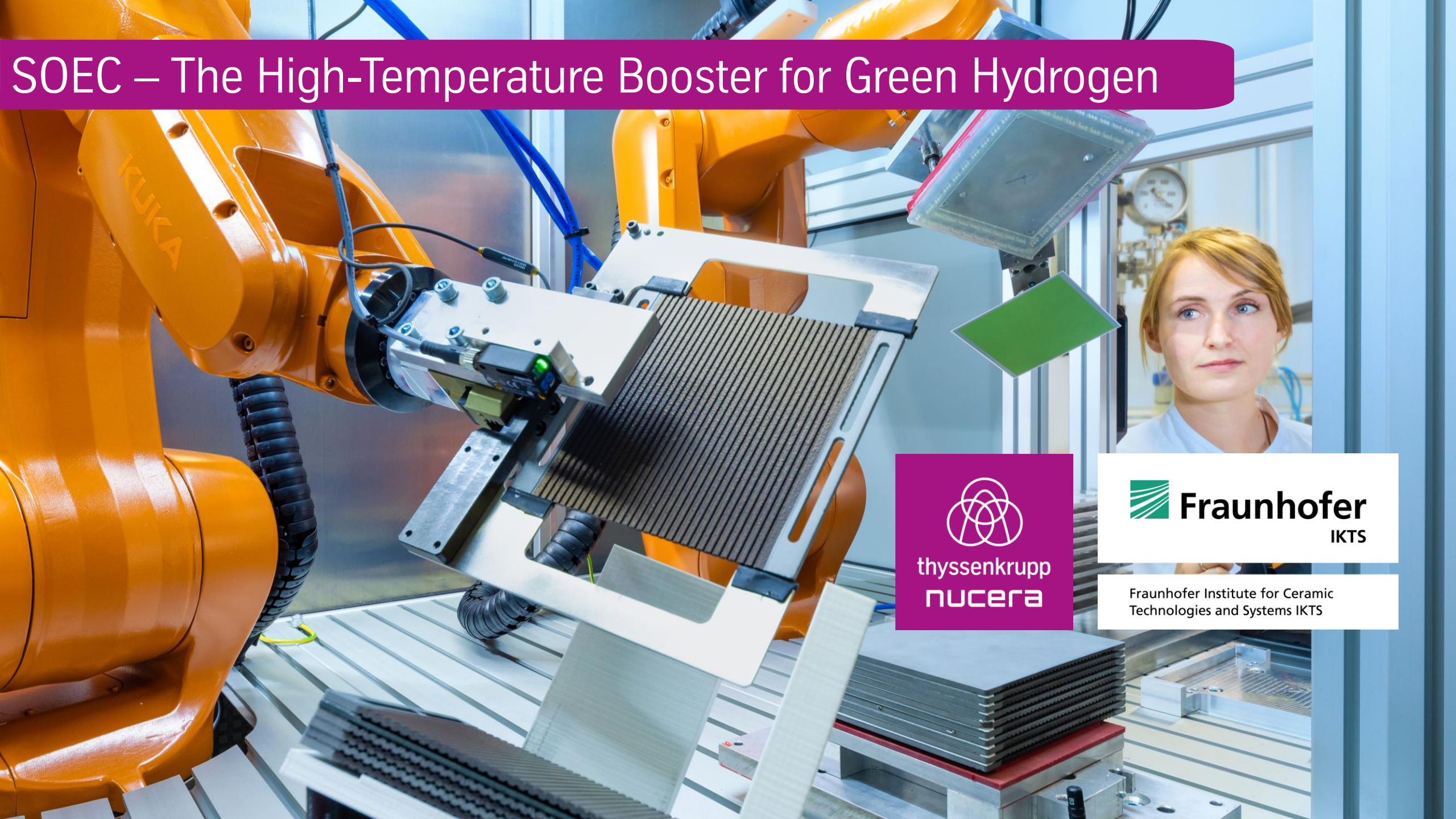
High-Voltage Test

- Fully automated high voltage test bench for Membrane Electrode Assembly (MEAs)
- Isolation and puncture test at test voltage to detect membrane defects

Cold Leakage Test

- Automated leakage test of joined stacks
- Automated clamp and test procedure without manual intervention for high process stability

SOEC – The High-Temperature Booster for Green Hydrogen

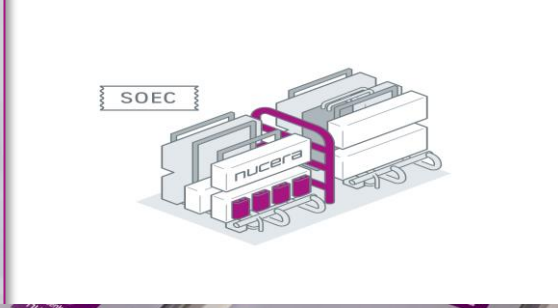


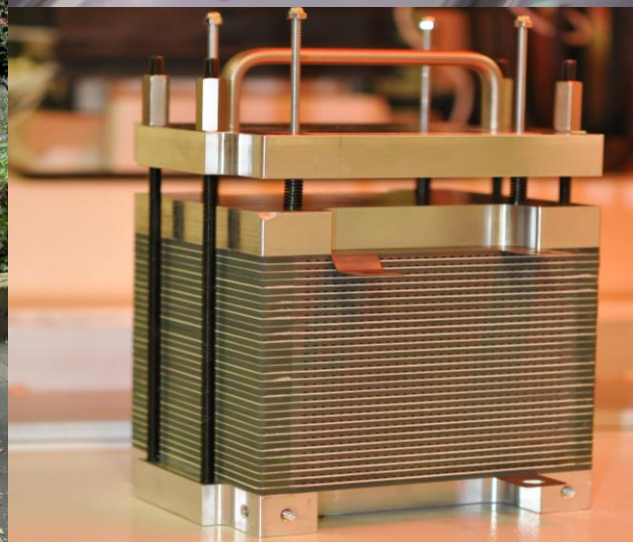
thyssenkrupp nucera

Fraunhofer IKTS

Fraunhofer Institute for Ceramic Technologies and Systems IKTS

#achievements



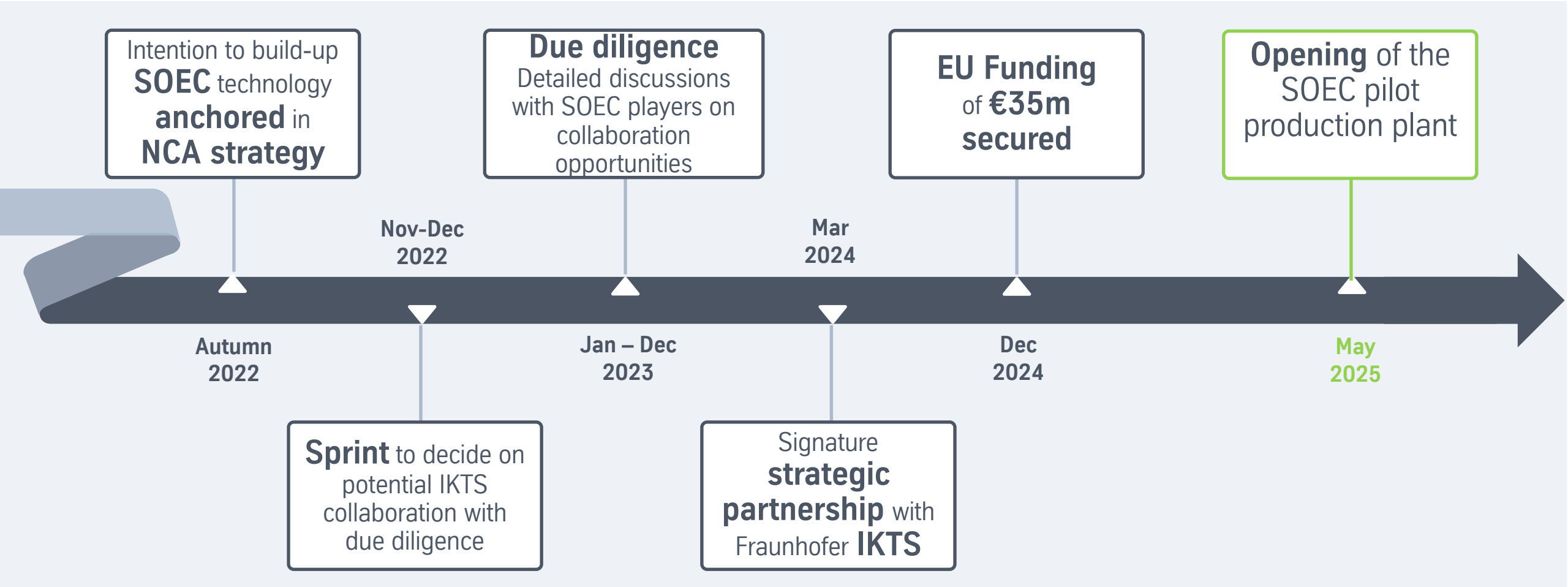


#SOEC Journey

Fraunhofer IKTS

Fraunhofer Institute for Ceramic Technologies and Systems IKTS

thyssenkrupp nucera



thyssenkrupp nucera and Fraunhofer IKTS: Strategic partnership to industrialize SOEC technology

NCA: Market leader in electrolysis technology for the production of green hydrogen

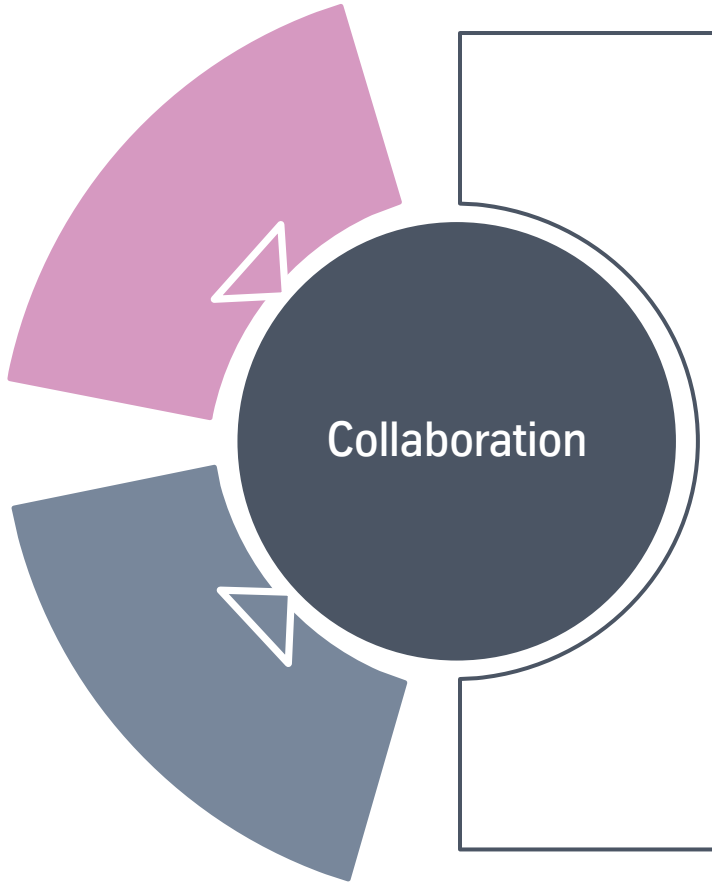
Target: Fast market entry into SOEC business and successfully scale-up from stacks towards plants

- Seeking for an excellent technology partner

Fraunhofer IKTS: Research institute[1] with over 25 years of experience in solid oxide electrolysis and fuel cell technology

Target: Advancing research, transferring stack technology to industry, and driving continuous innovation

- Seeking for a competitive stack production partner



- ✓ Fraunhofer IKTS and NCA can achieve their targets via close collaboration, highlighting their co-dependency
- ✓ This partnership enables NCA to
  1. Enter the market with SOEC technology towards plant size
  2. Target customers beyond core markets (Swiss army knife)

1. Located at the Arnstadt IKTS site, set-up and purchase of the pilot line not content of the current signing contracts

SOEC technology with clear advantages in certain conditions

SOEC technology advantages

Leading Efficiency

- 20-30% more efficient with excess heat, opening a niche market

Swiss Army knife

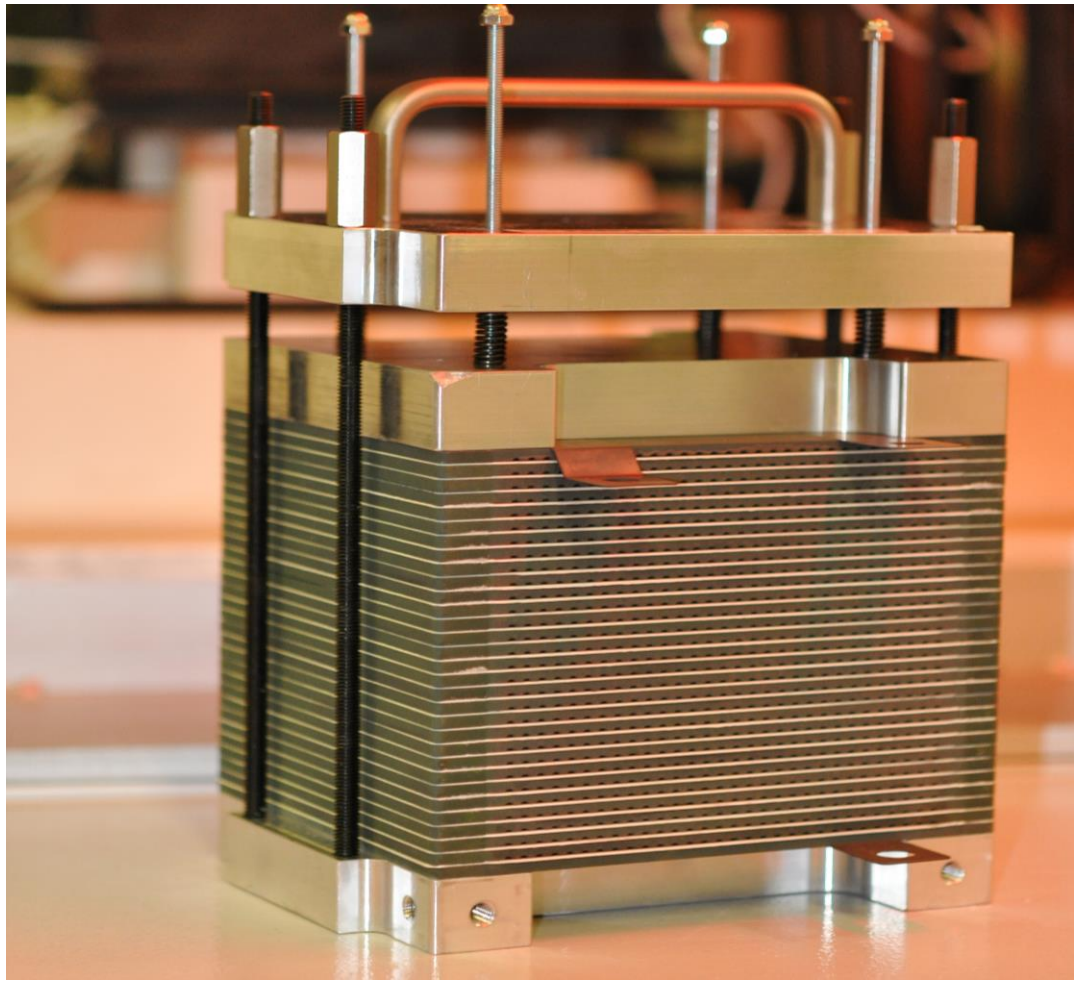
- Green Hydrogen
- Co-electrolysis (via Fischer Tropsch Synfuels)
- Ammonia (via Haber Bosch)

No PGMS & no PFAs

- Progress in reducing precious metals in other electrolysis technologies continues, but it's not a challenge for SOEC

High technology maturity

- Demonstrated functionality and ready for mass manufacturing (multiple 0.1 - 5 MW demonstrators live, in contrast to AEM)



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SOEC with multiple applications, also from potential integration with downstream processes

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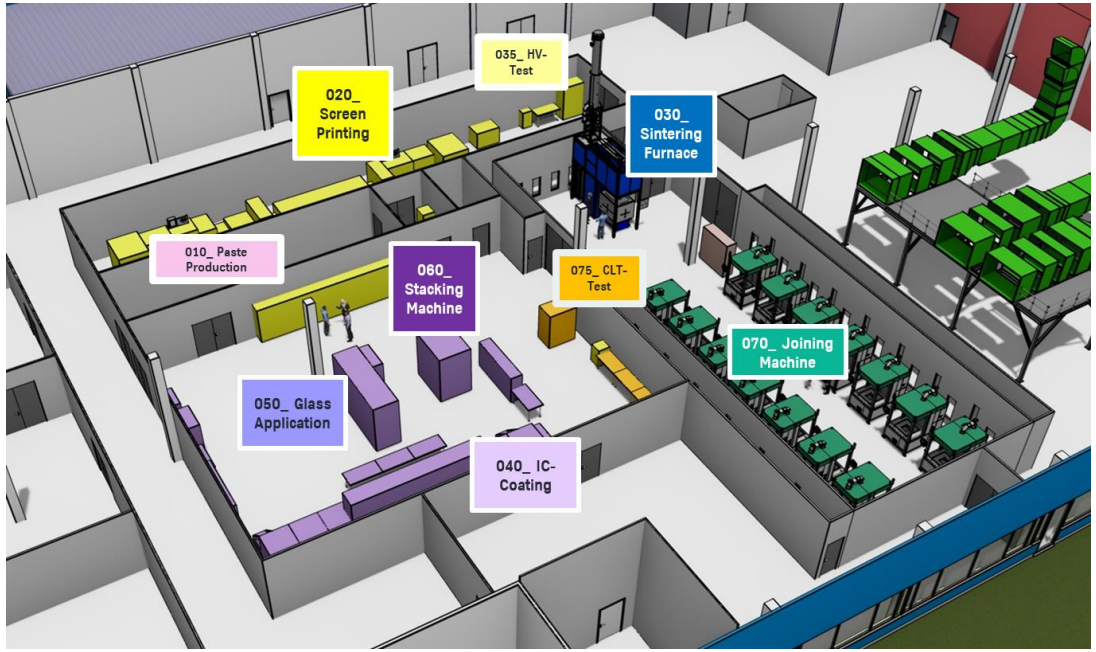
SOEC pilot production plant: From the paste to the stack



9x Paste

Paste - Production

Sintering

Screen Printing

7 Layer Cell

HV - Test

IC Coating

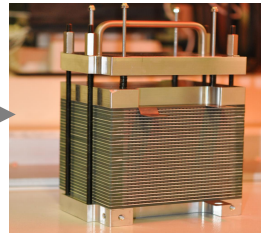
Stacking Machine

Joining Machine

Initializing & Performance Test

Cold Leakage Test

Packaging



Glass Application

Anode Spacer

Nickel Mesh

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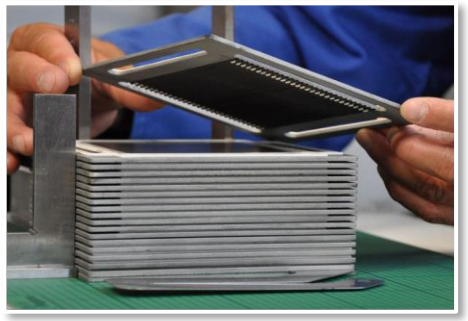
SOEC is highly promising given its leading efficiency and advancing technology readiness

	 Alkaline Water Electrolysis (AWE)	 Polymer Electrolyte Membrane (PEM)	 Solid Oxide Electrolysis (SOE)	 Anion Exchange Membrane (AEM)[1]
Technology readiness level				
Output	H_2	H_2	H_2, Syngas, CO	H_2
Average system efficiency	Good	Good	Very good (20-30 % more efficient)	n/a
PGM use	Not necessary, but enables high current densities	Needed	Not needed, but rare earth material required	Not needed, low cost material possible
Design parameter	1-30 bar and 70-90 °C	1-30 bar and 60-80 °C	1 bar and 600-900 °C	1-35 bar and 40-80 °C
Use	Medium and large scale	Deployment with intermittent electr. supply possible	Applications with const. high temperature steam	Deployment with intermittent electr. supply possible

1 AEM Enapter Enapter-Elektrolyse: Kompakt und modular vor dem Durchbruch (cleanthinking.de) https://www.chemie.de/lexikon/Wasserstoffherstellung.html

Fraunhofer IKTS thyssenkrupp nucera

CN

thyssenkrupp nucera: SOEC target picture 2030

Fraunhofer IKTS at a glance

Ceramics as driver of innovation

Fraunhofer IKTS: Europe‘s leading R&D institute for ceramics

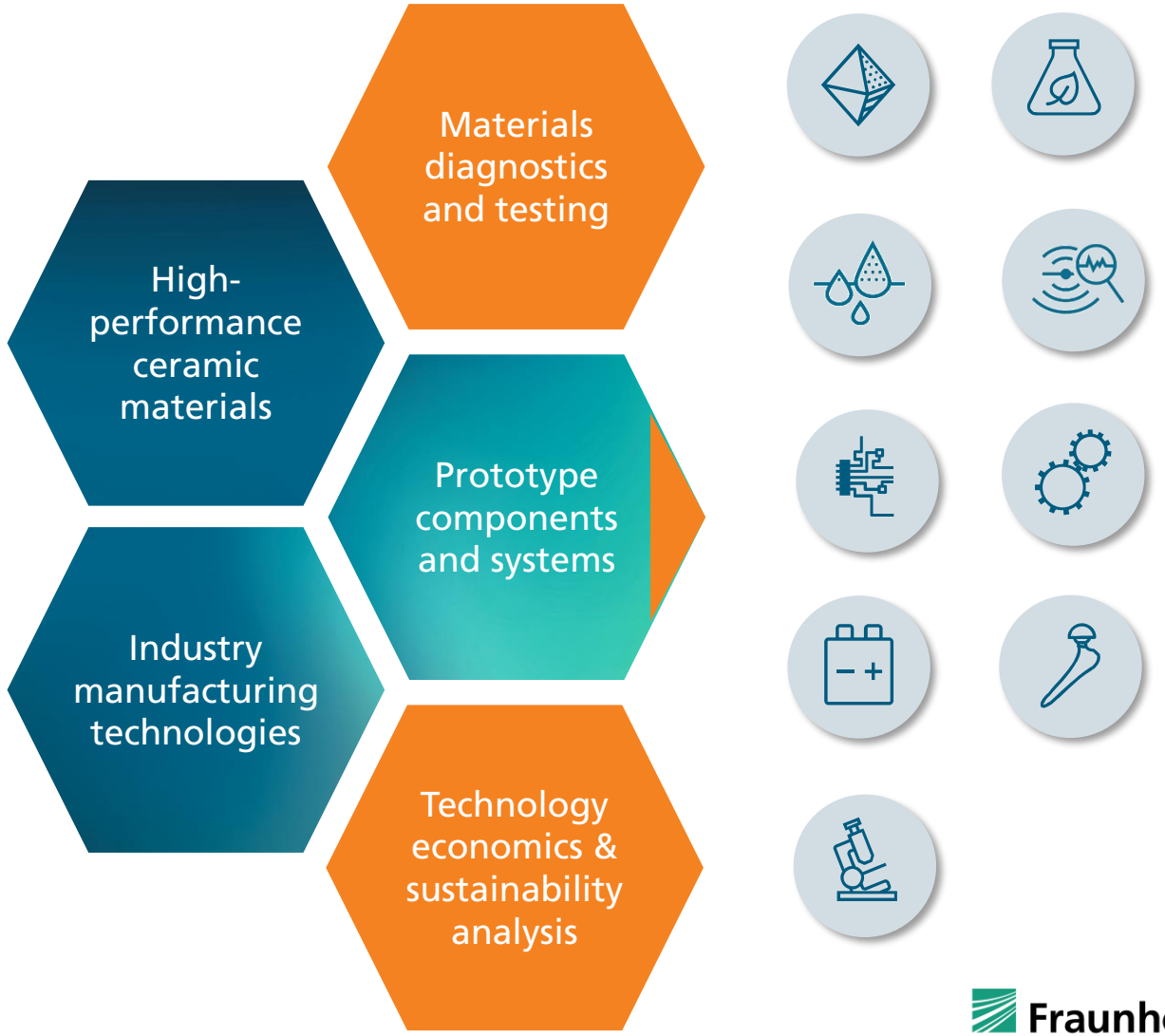
Research and technology service provider in the field of high-performance ceramics

- From materials to systems
- In complete production lines up to pilot-plant scale
- Including analyses of economic viability and sustainability

813 employees[1]

14 sites around Germany

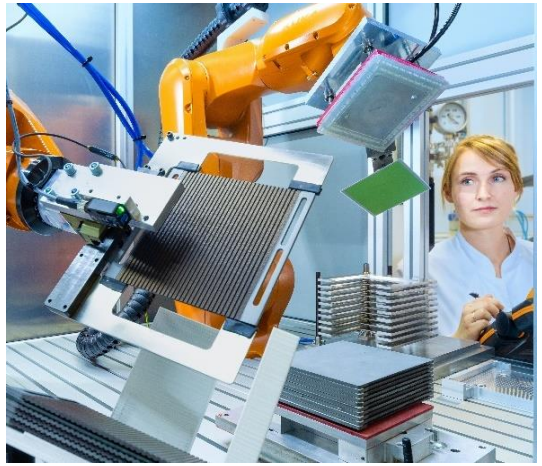
97.6 million euro overall budget[1]



1 Status December 31, 2024.

Fraunhofer IKTS

Fraunhofer IKTS: Europe‘s leading R&D institute for ceramics



Fuel cell and electrolysis technologies

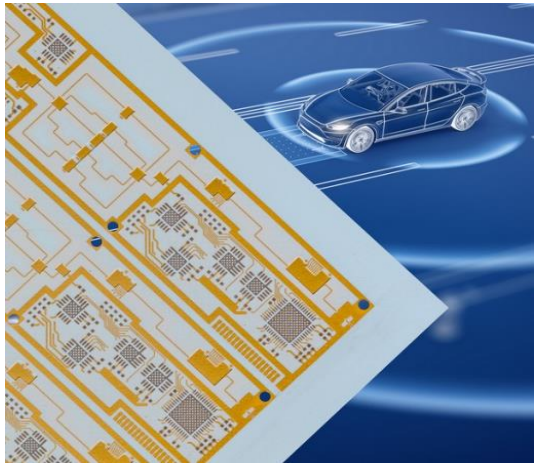
Fuel cells and high-temperature electrolysis cells – development and test from component to system.

Solutions for Li-ion and $NaNiCl_2$ batteries

Top-down and bottom-up development of new active materials and batteries

Recycling and wastewater treatment / gas separation

Process chain for water treatment and gas separation.



LTCC-based electronic packaging

Electronics for harsh environments and high-frequency boards

Fraunhofer IKTS

Fraunhofer IKTS: Leading developer in high-temperature electrolysis

- ✓ More than 30 years of experience in Solid Oxide Electrolysis (SOE).
- ✓ Extensive know-how across the complete value chain, from material to system, including analyses of economic viability.
- ✓ IKTS developments have culminated in the incorporation of very successful new companies.
- ✓ Development and production of SOE stacks and modules for the integration in electrolysis plants on a pilot scale.
- ✓ Optimization of materials, modules, and systems with regard to their long-term stability and performance.
- ✓ Main focus on developing and testing industrial-scale automated stack production and modularization concepts for high performance classes.

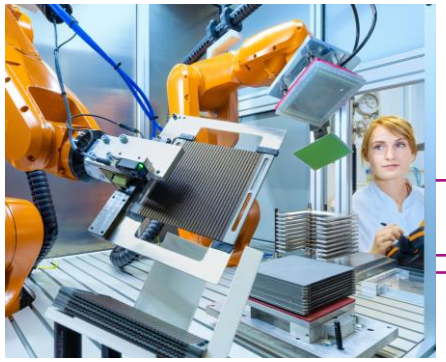
Fraunhofer IKTS

Fraunhofer IKTS approach: Hydrogen economy of the future

SOE

Water

CO_2



Renewable
heat & power

CO

H_2

Ptx

H_2

Fischer-
Tropsch

C_xH_y

e-fuels, chemical products

diesel, kerosene

H_2

Haber-
Bosch
goes green

NH_3

ammonia as H_2 carrier

Fuel cell

Ostwald process

N/S Fertilizer
for agriculture

H_2 / CO

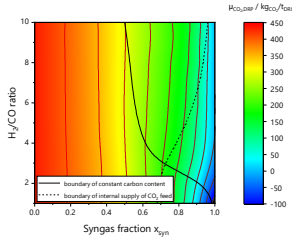
H_2

green
production

H_2

H_2 / CO

green steel



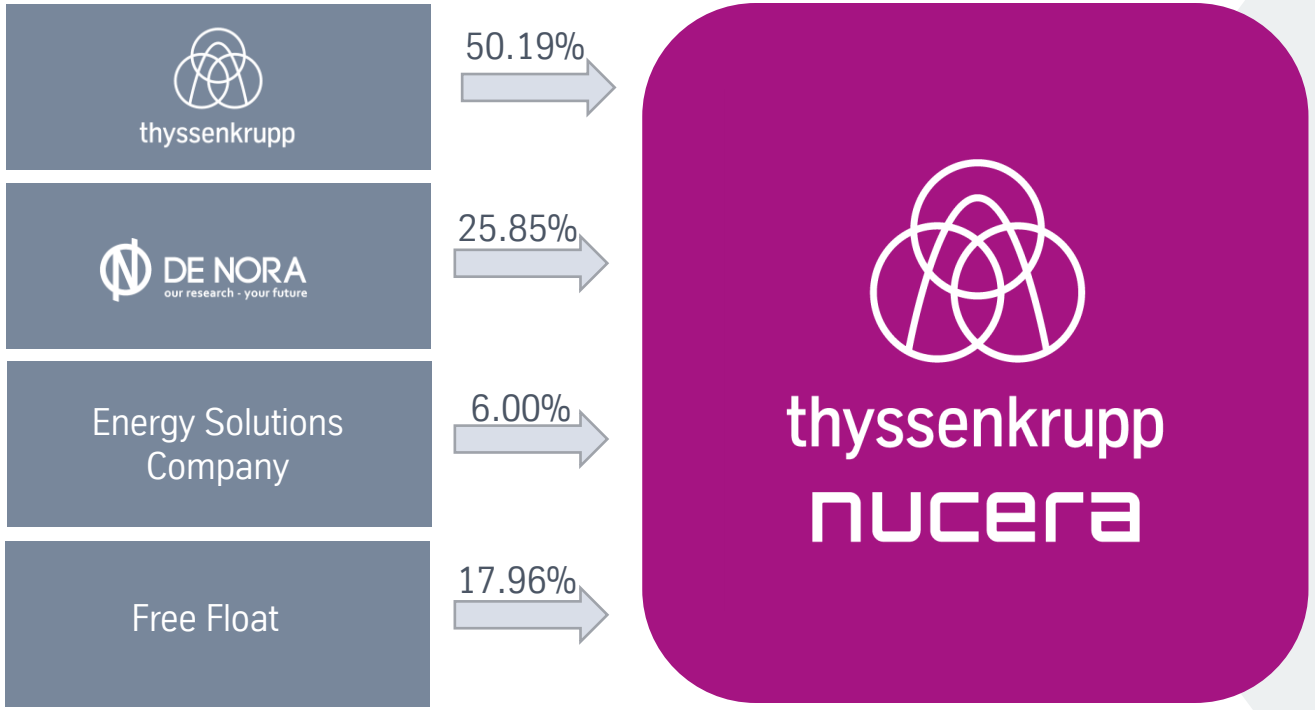
Fraunhofer
IKTS

thyssenkrupp nucera at a glance

We shape the new era.

thyssenkrupp
nucera

thyssenkrupp nucera: We are the Alkaline Water Electrolysis (AWE) and Chlor-Alkali (CA) technology provider globally



AWE

Order backlog FY 23/24: ~0.7bn €

Selected AWE customers

AIR PRODUCTS, CF, Stegra

CA

Order backlog FY 23/24: ~0.4bn €

Selected CA customers

covestro, Olin, BASF We create chemistry

thyssenkrupp nucera: At a glance

10
Locations

1,000+
Employees worldwide

600+
Successful electrochemical projects worldwide

>10GW
Electrolyzer capacity installed

3GW+
Contracted green hydrogen capacity

>1.5GW
Manufacturing capacity p.a. today

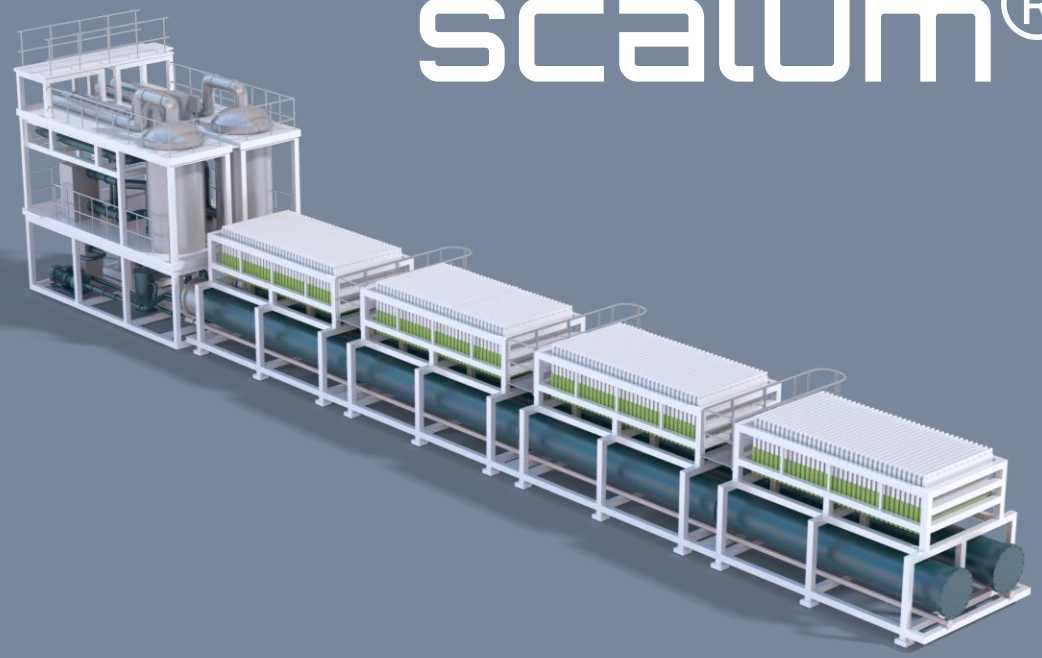
thyssenkrupp nucera: World-leading electrolysis technologies

- A global technology leader in large-scale electrolysis
- Global organization with reputable and long-standing partners
- Advanced bankability through solid track record
- Full fledged service offering along the entire plant lifecycle
- Strong R&D focus to drive innovations
- Best-in-class safety standards
- Proven GW-scale supply chain already in operation

Enabling green transformation

- ✓ AWE technology delivers speed and scale
- ✓ Based on proven quality, safety, reliability, and passion for innovation
- ✓ A powerful unit with ~ 300 high-efficiency cells
- ✓ Standardized modular solution with a system capacity of 20 megawatts (MW)
- ✓ Can be easily interconnected and scaled up to match highest demands, up to gigawatt plant size

scalum®



Quality and Longevity

High Performance

Design Certified

Global Service Network

Innovative CA and HCl solutions for industrial progress

Global leader
in electrolysis

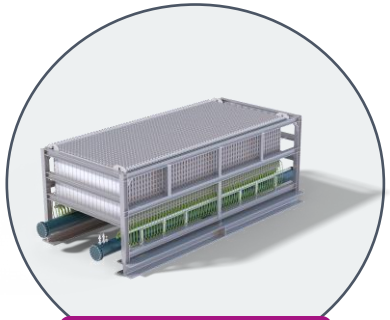
>10 GW
electrolyzer capacity installed[1]

Over 600
electrochemical projects realized

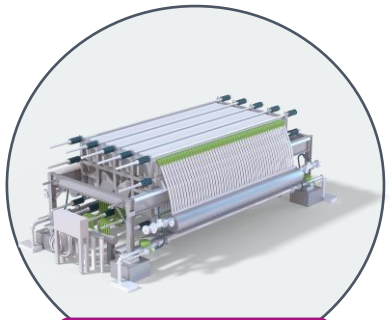
Over 240.000
electrolytic cell elements produced

Product Portfolio

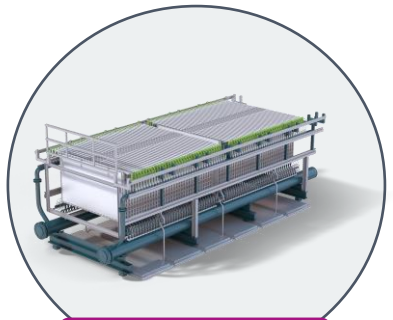
CA Electrolysis:
Local production of Chlorine (Cl_2), Caustic Soda (NaOH) and Hydrogen (H_2)



BM[2]

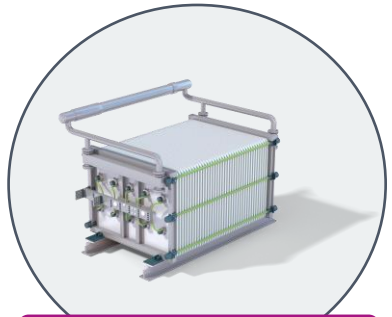


BiTAC[3]

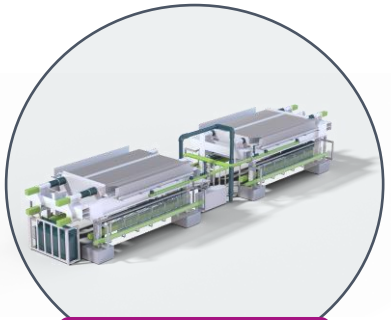


NaCl ODC[4]

Hydrochloric Acid (HCl) Electrolysis:
Recycling of HCl into Chlorine (Cl_2) and Hydrogen (H_2)



HCl Diaphragm



HCl ODC[5]

1. To produce chlorine and hydrogen 2. Bipolar membrane electrolyzer 3. BiTAC: Bipolar Tosoh and Chlorine Engineers 4. ODC: Oxygen Depolarized Cathode 5. Recycling HCl at low energy consumption

Contact:

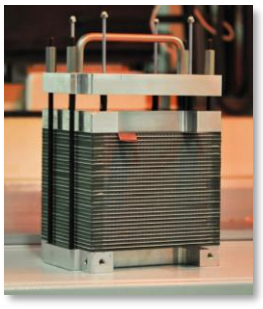
thyssenkrupp Nucera AG & Co. KGaA
Jan Patrick Domhardt
Managing Director HTE GmbH
Phone: +49 172 203 76 33
jan.domhardt@thyssenkrupp-nucera.com

Fraunhofer IKTS:
Dr. Roland Weidl
Deputy Institute Director Fraunhofer IKTS
Phone: +49 3628-58172-22
roland.weidl@ikts.fraunhofer.de

SOEC stack pilot plant – Arnstadt/Thuringia

Product

- SOEC-stack-technology (Solid Oxide Electrolysis)
- 20 – 30 % higher energy efficiency



A strong partnership

thyssenkrupp nucera

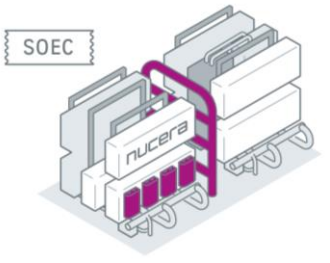
World leading provider for highly efficient electrolysis technology with 1.083 employees around the globe

Fraunhofer IKTS

Research institute with over 30 years of experience in solid oxide fuel cell / electrolysis technology with 813 employees at 14 sites in Germany

Capacity / Area

- 8 megawatts (MW) per year
- # 2.000 stacks per year
- 1.200 m^2 production area



Technology

- **Screen printing technology** for SOEC membrane-electrode-assemblies (MEA)
  - Precision coating of electrolyte materials, cleanroom integration
  - Inline process control – real-time monitoring of parameters
- **Coating process** for bipolar plates
  - Application of uniform, functional layers in the micrometer range
  - Inline measuring systems for process monitoring
- **Sintering furnace**
  - High-temperature process control during the sintering process
  - Homogeneous connection between electrolytes and electrodes for reliable electrochemical performance in SOEC operation
- **High-precision automatic punching machine**
  - Micrometer-precise contour punching of the glass tape to adapt to complex cell-stack-geometries
- **Stacking**
  - Micrometer-precise positioning of components with industrial robots
  - Camera-based detection and adjustment of every position
- **Joining**
  - Joining the individual cells to form a gas-tight stack
  - Use of process gases to prevent oxidation and for targeted electrochemical initialization
  - Precise, uniform force distribution across the entire stack-cross-section
  - Performance test after the joining process in reversible fuel cell operation (SOFC), to validate the thightness, electrical contacting and reactivity of the stack
- **High-voltage test (expansion stage 2)**
  - Fully automated high-voltage test for membrane electrode assemblies (MEAs)
  - Insulation and breakdown test at test voltages to detect membrane defects
- **Leak test stand (expansion stage 2)**
  - Automated leak test of joined SOEC stacks
  - Automated clamping and test sequences without manual intervention for high process reliability
- **Paste production (expansion stage 2)**
  - Production of screen printing pastes in the laboratory for functional layers of SOEC membrane electrode units
  - Paste preparation/characterization and their processing on roller mills

Important Links (Photos & Videos)

- **Press release:** Press releases - thyssenkrupp nucera (thyssenkrupp-nucera.com)
- **Photos & Videos (products, management, HQ):**
  thyssenkrupp nucera: Publications & Media - thyssenkrupp nucera (thyssenkrupp-nucera.com)
  Fraunhofer Institute for Ceramic Technologies and Systems IKTS:
  Press/Media – Fraunhofer IKTS
- **Interview with Professor Alexander Michaelis and Dr. Werner Ponikwar on SOEC "Shaping the Green Energy Future":** Shaping the Green Energy Future - thyssenkrupp nucera (new-era-insights.com)
- **Brochures**
  thyssenkrupp nucera: Rethinking existing infrastructures | Startseite - thyssenkrupp nucera (thyssenkrupp-nucera.com)
  Fraunhofer Institute for Ceramic Technologies and Systems IKTS:
  Flyer: Fraunhofer IKTS in profile
  Brochure: Hydrogen Technologies
  Infographic: Value chain for green hydrogen
- **Webseite:**
  thyssenkrupp nucera: Rethinking existing infrastructures | Home - thyssenkrupp nucera (thyssenkrupp-nucera.com)
  Future Solutions - thyssenkrupp nucera
  Fraunhofer Institute for Ceramic Technologies and Systems IKTS:
  www.ikts.fraunhofer.de/en.html
  Quick introduction: Strategic partnership in SOEC technology - Fraunhofer IKTS
- **Glossary:** Glossary - thyssenkrupp nucera (thyssenkrupp-nucera.com)