Fraunhofer

FRAUNHOFER IN INDIA

NEWSLETTER - ISSUE 2021

Emerging Technologies : Mobility and Hydrogen

Content

FOREWORD

Dear Readers,

In March 2020, when the first wave of Covid hit India, little did we know what was in store for us. India just like the rest of the globe, went through an unbelievable Sci-fi like situation, with complete lock downs, no travel and hardly any contact with others. For a research organization to pull back from labs, reduce client contact to the bare minimum and conduct research in isolation is like declaring the death knell. However, Fraunhofer like most of its peers showed an immense resilience and worked even harder to bring the benefits of innovation and research faster to the society.

The Fraunhofer-Gesellschaft addressed the challenge with a series of sustainable measures, starting with securing immediate initial funding for urgently needed research, running to several million euros. In the words of Prof Dr Ing Reimund Neugebauer President Fraunhofer Gesellschaft, "The focus was on projects in the medical and health sectors of direct relevance to the coronavirus crisis, including the development of a vaccine, innovative diagnostic techniques, development of new drugs, putting into place a powerful IT infrastructure, and prioritizing relevant pre-competitive research."

On the other hand, it was quite impressive how the industry stood up to this challenge. In India, we have been working with the Industry and the Government on a number of innovative programmes and projects in a variety of areas including Health, Artificial Intelligence, Water Innovation Hubs, Digitalisation & Industry 4.0, Renewable Energy and E Mobility. Our work in supporting the development of an innovation ecosystem has been most rewarding, and we are excited to launch some of these projects which call for multi-stakeholder involvement and development of innovative technologies that accelerate the path to market. The fact that Fraunhofer works with a variety of innovation players from Start-ups to SMEs and large companies as well as the logistics and service providers, gives us a broad as well as deep understanding of the innovation value chain, which in turn has been instrumental in our work in several countries like Brazil, China, Dubai, Israel etc. where we supported and advised the setting up of cluster initiatives, as well as innovation centres. Our own spin offs have been the focus of several large investments, the latest being Nexwafe, a spin off from Fraunhofer Institute of Solar Energy (ISE) in Freiburg. Reliance New Energy Solar Limited (RNESL), a wholly owned subsidiary of Reliance Industries Limited (RIL), invested 25 million Euros ($29 million) in Germany's Nexwafe GmbH and will be the strategic lead investor for the German company's €39 million Series C financing round. NexWafe has a proprietary technology that can significantly reduce the cost of producing photovoltaic (PV) cells and could make solar photovoltaics the lowest cost form of renewable energy available. The technology is to develop and produce monocrystalline silicon wafers directly from cheap raw materials, going directly from the gas phase to finished wafers without costly and energy intensive intermediate steps.

Another area which is of prime focus for Fraunhofer in India is Mobility. We have been extremely active in the field of battery technologies, charging infrastructure, as well as last mile E Mobility solutions. Our projects with several partners including the World Bank, Government, Industry and Research are exciting and path breaking.

I am delighted to bring to you a sample of our extensive work in these fields, and showcase some of the technologies that will define our work and life in the years to come. We have also tried to encapsulate some of our activities during the Covid times, and share the sentiment of indomitable human spirit that services the toughest of times and situations.

We hope you will enjoy reading them, and as always, we look forward to your feedback and engagement.

With warm regards,
Anandi Iyer

FRAUNHOFER PROFILE
India Highlights

The Fraunhofer-Gesellschaft, headquartered in Germany, is the world's leading applied research organization. Fraunhofer plays a central role in the innovation process with its focus on developing key technologies that are vital for the future and enabling the commercial exploitation of this work by business and industry. As a pioneer and catalyst for ground-breaking developments and scientific excellence, Fraunhofer helps shape society now and in the future. Founded in 1949, the Fraunhofer-Gesellschaft currently operates 75 institutes and research institutions throughout Germany. The majority of the organization's 29,000 employees are qualified scientists and engineers, who work with an annual research budget of 2.8 billion euros. Of this sum, 2.4 billion euros are generated through contract research. Our global footprint is very strong, with offices and research centres in the USA, Europe and Asia. Fraunhofer's renowned innovations include the MP3 software, white LED's and the smallest of cameras.

Fraunhofer has been active in India since the past several years, bringing innovative technologies and research competence to India. In recent years, various Fraunhofer technology competencies in the sectors of Energy & Environment, Production Technology & Industry 4.0 and Smart Cities were introduced and promoted by Fraunhofer Office India and many strategic partnerships were initiated with Government (affiliated nodal agencies, PSU's) and private sector. As many as 54 out of 75 Fraunhofer institutes have an active presence in India. Over the last 10 years, Fraunhofer has generated over 45 Million Euros in Contract Research/Technology collaboration from India.

Highlights of Fraunhofer's Strategic cooperation in India:

- Fraunhofer has an MoU with DHI to be the "Technology Resource Partner for Manufacturing in India" and support SMEs as well as public sector companies to upgrade their technologies and Innovation capability.
- MNRE (National Institute of Solar Energy NISE) and Fraunhofer ISE have signed MoU to strengthen their cooperation in the field of Solar Energy, RE, Hydrogen and fuel cells systems.
- International Solar Alliance (ISA): Fraunhofer Partnership: Fraunhofer ISE to be as Technology partner for ISA. Ms. Anandi Iyer represents Fraunhofer at the International Committee member of ISA for developing guidelines and implementing Technical Standards for Solar Applications
- Smart City Innovation Labs have been established in Coimbatore, Kochi and Solapur.
- Strategic Cooperation with CSIR, Govt. of India: Fraunhofer and CSIR signed an MoU to promote, establish and expand Scientific and Technological Research Cooperation between India and Germany on the joint research topics - Battery Technologies, Sustainable Building Technologies, Water Management and Advanced Production Technologies.
- Cooperation with IIT - Madras to establish a Centre for Advance Automotive Research (CAAR).
- Cooperation with IIT - Jodhpur and O/o PSA to Govt. of India for India's S&T cluster: to establish a Water Innovation Hub with focus on Advanced Wastewater Treatment for Jodhpur Industrial Cluster.
- MoU with ACMA, SIAM and NATRiP for the Automotive sector for light weighting and allied technology support.
- Contract with Delhi Integrated Multi-Modal Transit Systems Ltd. (DIMTS), Govt. of Delhi to induct 1000 low floor electric buses in Delhi.
- Cooperation with Solar Energy Corporation of India (SECI), Govt. of India on PV Manufacturing and Quality-Standards.
- NITI Aayog*, Govt. Of India – on strategic (Technical) support for Digitalisation and Battery Technologies.
- Fraunhofer is a knowledge partner to IMTMA for Indian Metal-Cutting Machine Tool Exhibition (IMTEX).
- Cooperation with IWTMA (Indian Wind Turbine Manufacturing Association)
- MoU with BML Munjal University for setting up advance qualification courses.

Fraunhofer assists companies in the development, optimization and market introduction of products and processes by:

- Developing new products and services
- Improving products
- Optimizing existing processes and organizational structures
- Moving from product development to short-run production
- Market analysis and feasibility studies
- Incorporating new technologies
- Licenses
- Characterization, testing and certification

Fraunhofer also contributes in a significant manner to developing the innovation ecosystem in the country. In this regard, Fraunhofer is a member on important councils with FICCI, CII, TSDSI, NASSCOM, IMTMA etc to share the learnings and expertise


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Mobility: Innovations of the future

Source : Fraunhofer Institute for Industrial Engineering IAO

Mobility has undergone a major transformational shift of generation, with far-reaching implications for the way we live our lives. It has been shaped by three disruptive forces mainly, alternative powertrains and electric vehicles, on-demand mobility services, and connected and autonomous vehicles. While some sectors have disappeared entirely, some others are converging or being disrupted. It all depends on how each sector grabs the right emerging opportunity and adapts the right business and operating models. With an increased population growth and urbanization, it becomes necessary to welcome new forms of mobility in order to support the future population hubs and economic activities. The future of mobility promises safety and convenience with very little impact on health and the environment.

How will innovations arise in the future? Increasingly shorter development cycles, many different technological opportunities and entirely new forms of teamwork are changing workplace processes of innovation. They will also affect market conditions and customer behaviour in the long term.

In the scope of diverse research projects, scientists on Mobility and Innovation Systems teams work on solutions and methods for conceiving, designing and introducing product, process and service innovations. These interdisciplinary project teams always pursue a holistic approach that is compatible with technology, people and the environment. Research pursuits emphasize close cooperation between the domains of mobility, energy, information technology and communications technology. To ensure that Fraunhofer translates theory into practice, Fraunhofer tests approaches on its own fleet of electric vehicles, in its smart microgrid living lab or in our in-house mobility innovation lab, which is a prototyping facility as well as a creativity space for ideation and expert workshops.

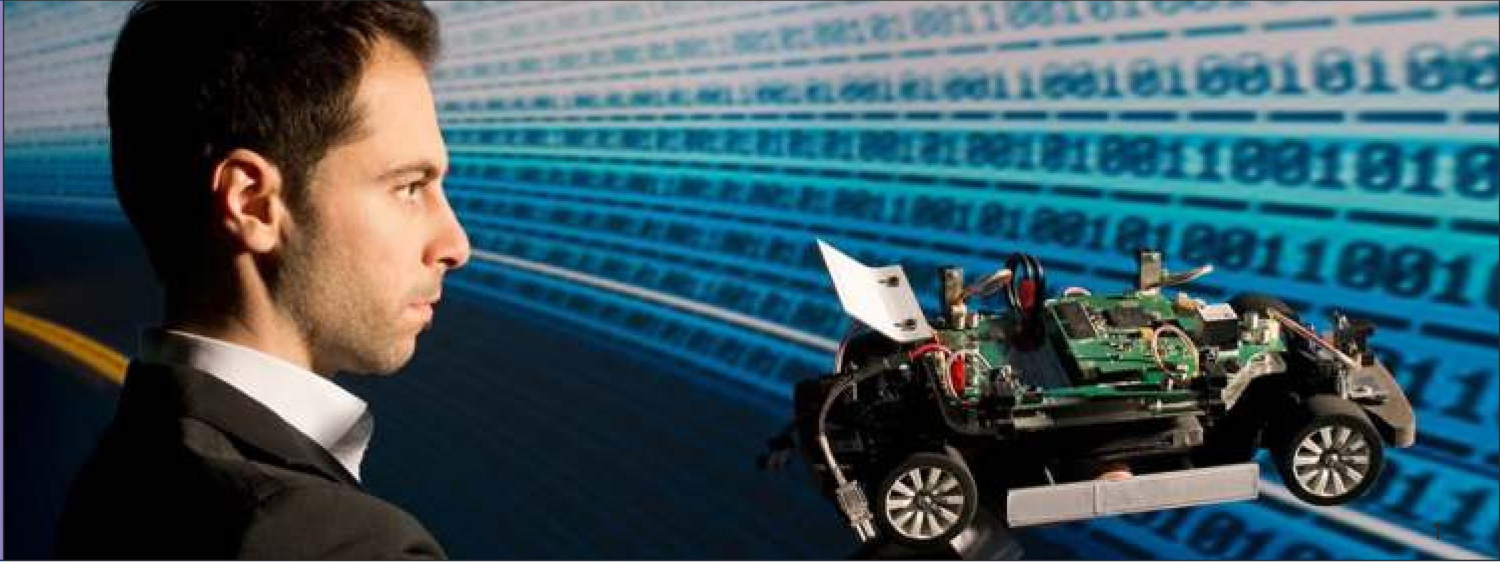
Fraunhofer's key areas of research include:

- Trend research and big-data analyses for the development of strategic and business models
- Identification and evaluation of technological and market developments
- Development of mobility concepts and guiding principles for mobility
- Assessment and conceptual formulation of business and operation models as well as mobility services
- Planning and dimensioning of integrated energy solutions and charging infrastructure for electric vehicles
- Ideation and prototyping of innovative technologies for the vehicles of tomorrow
- Scientific guidance on transformation processes
- Development of cooperative formats for research, participation and workshops
- Research on user acceptance of mobility innovations

Fraunhofer Member Institutes include:

Fraunhofer Center for Applied Research on Supply Chain Services SCS
Fraunhofer Research Institution for Large Structures in Production Engineering IGP
Fraunhofer Institute for Industrial Engineering IAO
Fraunhofer Institute for Building Physics IBP
Fraunhofer Institute for Structural Durability and System Reliability LBF
Fraunhofer Institute for Digital Media Technology IDMT
Fraunhofer Institute for Factory Operation and Automation IFF
Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM
Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR
Fraunhofer Institute for Material Flow and Logistics IML
Fraunhofer Institute OF Optronics, System Technologies, and Image Exploitation IOSB
Fraunhofer Institute for Physical Measurement Techniques IPM
Fraunhofer Institute for Systems and Innovation Research ISI
Fraunhofer Institute for Industrial Mathematics ITWM
Fraunhofer Institute for Transportation and Infrastructure Systems IVI
Fraunhofer Institute for Nondestructive Testing IZFP
Fraunhofer Institute for Photonic Microsystems IPMS
Fraunhofer Institute for Experimental Software Engineering IESE
Fraunhofer Austria Research GMBH
Fraunhofer Institute for Applied Optics and Precision Engineering IOF

2. The Mobility Innovation Lab is a modern research facility for prototyping and creative workshops. A converted car interacts with a pedestrian



Mobility Innovation: A home away from home

Source : Fraunhofer IAO | Mobility, Urban Systems Engineering and Innovation Systems

Bringing the future of mobility to life

At the heart of this initiative to pursue the most promising ideas is Fraunhofer IAO's Mobility Innovation Lab in Stuttgart. This modern research facility for prototyping and creative workshops already provides an insight into the mobility of tomorrow, featuring, for instance, a converted vehicle that interacts with pedestrians; an electric three-wheel scooter that hints at the future of sustainable inner-city mobility; and a futuristic car cockpit complete with modular dashboard, windows made of switchable glass, reclining seats, fold-out tables and a pull-out monitor – a glimpse into the cockpit of the future and how it might interact with future on-board electronics and services such as language learning, pizza delivery or personalized entertainment.

Image Courtesy: © Bernd Müller, Fraunhofer IAO

Cars of the future will be much more than simply modes of transportation, gradually evolving to become "homes away from home" – places for people to work or unwind in a new age of autonomous driving. In a newly founded innovation network, researchers from the Fraunhofer Institute for Industrial Engineering IAO have joined forces with McKinsey & Company and a range of industry project partners to collaborate on the mobility solutions of tomorrow – from conceptual idea to finished prototype.

Cars of the future will be fully automated, transforming drivers into passengers – people who are no longer occupied with paying attention to the road, and who may have the desire or even the need to divert themselves with other activities. With vehicles steering, accelerating and braking entirely by themselves, drivers are freed up to admire their surroundings in a whole new way through the windshield display, or simply dim the windows and settle back to watch a movie. The car's interior has been transformed into an office or living room. Sebastian Stegmüller, researcher at Fraunhofer IAO, is familiar with the scenarios and believes they could become a reality in just a few years. Together with his team, his job is to look at the various ideas that are emerging, and determine as quickly as possible which technologies, services and business models could catch on and which of them are unlikely to succeed in the marketplace.

An automotive industry in flux

To conduct their research, Stegmüller and his colleagues have joined forces with management consultancy McKinsey & Company. Through the Mobility, Experience and Technology Lab, or MXT for short, the two partners are establishing a network that endeavours to bring the future of autonomous driving to life. This includes analysing trends to support businesses in making decisions on innovation projects. "Our job is to pick out the most promising ideas at the beginning of the innovation lifecycle, even before product development has begun," explains Stegmüller. In that way, the collaboration partners are doing their part to respond to the overwhelming wave of potential new innovations presented by the next big trends in the automotive industry: automation, vehicle connectivity and electrification, as well as new mobility services. "Business will have to reposition itself to respond to the digital transformation, but this also offers the opportunity for whole new mobility services and driving experiences," says Stegmüller, who heads the Mobility Innovation department. One solution, for instance, envisages voice-assisted services that draw on artificial intelligence, with car windshields turning into multifunctional displays. "Imagine, for instance, that the ticketing service popped up on the display while you were driving past the opera house. You'd be able to book your Aida tickets while you were driving by," says Dr. Tobias Schneiderbauer, Project Manager at McKinsey & Company.

Through their research, the partners in the innovation network are creating a founded basis for lucrative business models and technologies. This targets not only automotive manufacturers and suppliers, but companies from the entertainment and IT sectors as well. The partners have also taken care to bring on board businesses, municipalities and other stakeholders who support and enrich the network with their particular expertise. The network remains open to any company wishing to be involved with the MXT Lab.

Study into the mobility of tomorrow

One of the key roles of the MXT Lab is to carry out user studies, providing a first indicator of the viability of potential innovation opportunities. In one of the first such studies, the partners investigated whether the time freed up by autonomous driving might be suited to language learning. On top of a quantitative online survey conducted in Germany, China and the U.S., the researchers also set up an experiment at the lab to gather qualitative user feedback. The goal was to assess the underlying demand for these sorts of services as well as the attractiveness of various technical solutions and driving-related applications. This information allows the researchers to draw conclusions that can then be fed into the automation of the driving experience in the future and the way that these vehicles are designed.

What does mobility of the future look like?

Researchers from six Fraunhofer Institutes have developed a ground-breaking vehicle concept that can be flexibly and individually designed depending on the intended use. The concept calls for a modular passenger cell, following the logic of a shell principle, that can be flexibly adapted to the individual needs of the travellers: during the day, it serves as a communicative lounge; at night, it becomes a peaceful capsule for rest and recovery on long-haul trips. The interior can be adjusted flexibly and adapted in terms of settings. The materials used are made from renewable sources or are designed to optimize their ability to be reused or recycled. The entire module can be coupled with various mobility bases – with a vehicle platform, an air taxi, or Hyperloop solution, depending on the need. It can also be transformed into an interactive virtual-reality lounge that enables limitless virtual travel around the whole world, thus contributing to an innovative component of new mobility and building designs.

"The foundation of our mobility concept is the autonomous, light, and personalized AllCell, which is compatible with various platforms. The AllCell can drive or fly, always under the power of the most efficient fuel," explains Dr. Torben Seemann, who – in his role as the head of Smart Matrix Production at Fraunhofer IST. A special feature of this concept is the sustainable vehicle structure, which is divided into long-lasting reusable components and nondurable wear components, as well as design-relevant components. "The durable components are recycled after their end of life and reused in new vehicles. The nondurable parts are designed to achieve material recycling levels of nearly 100 percent," explains Dr. Philipp Rosenberg, head of the lightweight structures group at Fraunhofer ICT.

Fraunhofer IST, one of the member institutes at the Fraunhofer project center in Wolfsburg – is playing a critical role in the development of the mobility concept. "Our concept is the luxury edition of individual travel. The exterior, interior, and information and communication technology are modular, customizable, and adaptive to the context. The interior of the AllCell can be easily modernized and is always on the cutting edge in terms of technology," says Sebastian Stegmüller, head of the Mobility Innovation department at Fraunhofer IAO.

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The Fraunhofer Project Centre Wolfsburg: Resource-efficient lightweight construction, flexible production and future interior for future mobility carriers

Source : Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM

The transportation industry is facing massive challenges. Whether cars, ships, planes or trains, eco-friendly and climate-compatible mobility requires more efficient mobility solutions, resources efficient production technologies as well as holistic mobility concepts for new utilization concepts. There are several possible solutions: alternative drive systems, automated processes, digitization and networking, autonomous driving.

Another approach is to reduce the weight of vehicles and use multimaterial solutions made from renewable and sustainable raw materials. The strategic application of multimaterial solutions and modular smart interiors offers high potential for further developments and extensive use in mobility carriers. At the same time, progress in digitally networked manufacturing processes for hybrid components accelerates the use of these new lightweight materials.

The Fraunhofer Project Center Wolfsburg is specialized on bio based, multifunctional lightweight structures for all transport types and focuses on three major research fields based on the development of new alternate drives for electric or hydrogen propulsion and customization of interior with respect to a resource efficient and smart lightweight design, networked manufacturing processes and functional integration.

- Flexible production
- Battery module construction
- Future Interior

With its research expertise and innovative spirit, the Fraunhofer Project Center Wolfsburg supports manufacturers and suppliers developing sustainable solutions and their introduction into market from raw materials to new forms of flexibility in manufacturing processes and process chains to the recycling of components and materials.

Network of industry and research

The common goal is to develop materials, manufacturing and production technologies suitable for large-scale Films IST production for the economically and ecologically sustainable manufacture of hybrid lightweight components made of metals, plastics and textile structures.

The Fraunhofer Project Centre Wolfsburg
Image Courtesy: Fraunhofer IFAM

For the research and development of hybrid components of the future, the Open Hybrid LabFactory e. V. (OHLF), the TU Braunschweig and the Fraunhofer Gesellschaft are providing a joint platform for industrial partners and the public institutions involved. This so-called lightweight design campus "OHLF" is considered one of the leading addresses in this field in Germany. Within the framework of a new type of cooperation model - with science and industry at eye level - a unique infrastructure has been created where ideas become innovations.

With the spirit of current FutureLabs new technologies, processes are developed and their marketability and economic sustainability practically validated and applied for a serial production in a close collaboration between researchers, experts and developers from Fraunhofer and private partners. A perfect environment for this purpose was created in the Open Hybrid LabFactory e. V. (OHLF), where a consortium of scientific partners, world market leading companies and highly innovative small and medium-sized enterprises was formed.

This public-private partnership was initiated in 2012 under the leadership of the Automotive Research Center Niedersachsen (NFF) at the TU Braunschweig and is funded as part of the "Research Campus" initiative of the German Federal Ministry of Education and Research (BMBF).

In addition, the Fraunhofer Project Center Wolfsburg also works closely with the Fraunhofer Project Center for Energy Storage and Systems ZESS in Braunschweig.

Together, they are developing intelligent solutions for vehicle integration of the next-generation battery. This includes their production as well as the development of corresponding components derived from the use of alternative drives.

Four Fraunhofer institutes combine their expertise as part of the Fraunhofer Project Center Wolfsburg on a shared campus:

- Fraunhofer Institute for Manufacturing Technology and Advanced Materials Research IFAM
- Fraunhofer Institute for Machine Tools and Forming Technology IWU
- Fraunhofer Institute for Wood Research, Wilhelm-Klauditz-Institut WKI
- Fraunhofer Institute for Surface Engineering and Thin Films IST

2. & 3. Fraunhofer Project Centre

The Magic Word is Green House-Gas-Reduction Costs

An interview with

Mr. Ruediger Heim

Director of R&D Division "System Reliability" at Fraunhofer Institute for Structural Durability & System Reliability LBF

Mr. Ruediger Heim was working for almost 15 years for automotive engineering supply companies before he joined Fraunhofer in 2005. Since 2008 his focus is on more sustainable, cost efficient future mobility which meets all the safety and reliability requirements.

The Fraunhofer LBF is one of the leading institutes for research services for the mobility industry, especially for car and truck manufacturers and their suppliers. What are your focal points and special competencies?

The LBF always looks at the different transport systems in their respective context, i.e. how cars, trucks or rail vehicles are used, what loads occur with what frequency and what load limits need to be observed. In addition to the loads from operation and use, we also consider the material, design and production which in turn enables us to find an optimum for costs, weight and customer benefits. This is where a new and very exciting chapter begins, especially for the automotive industry. For example, manufacturers lack the many years of experience needed to design reliable electric vehicles. Hence research services in the field of reliability, safety and lightweight construction are currently in demand as never before!

Keyword electromobility: How do you see the development on an international scale?

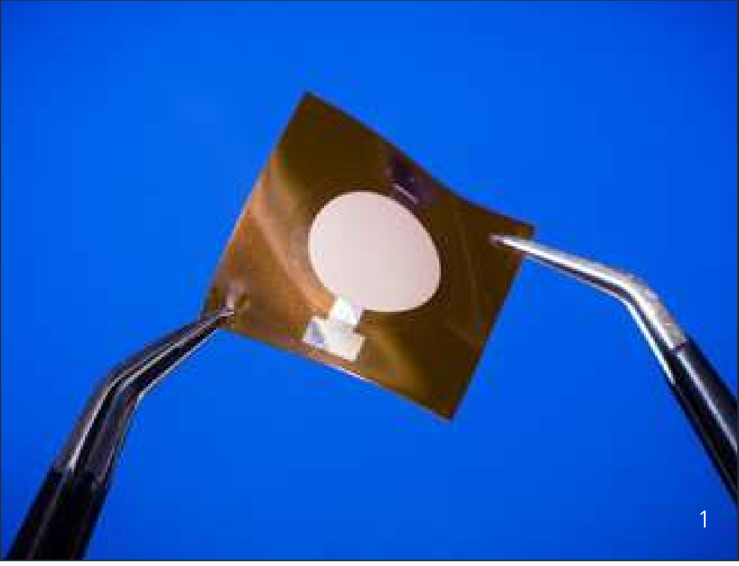
In Europe, we are very largely committed to battery electric vehicles. Also, some of the world's most successful manufacturers of zero-emission vehicles are found in the USA and in Korea. In China, too, the path is set. In all cases we see government subsidies for such vehicles, with the respective governments intervening very clearly in the technology autonomy of manufacturers. Although this is certainly conducive to a rapid shift away from the internal combustion engine, it creates major challenges elsewhere. The vehicle itself drives emission-free, but the energy storage systems are large, heavy and expensive. Till date, the development of the necessary charging infrastructure is an issue that has been completely underestimated. Neither the vehicle manufacturers nor the vehicle owners see themselves responsible for a large part of the changing infrastructure. Most people tend to look to the governments. With electromobility, the governments will be faced with unprecedented investment tasks, which will then reduce the scope for financing elsewhere. Therefore, it is not certain whether electromobility will also work for developing and emerging countries.

What alternatives can there then be for these countries?

Mobility is a basic social need and at the same time a basic economic prerequisite. In Germany, for example, the proportion of the transport performance in goods transport has increased since 1950 almost the same as the gross national product as a measure of the overall economic performance. In other words, without mobility and transport, developing and emerging countries in particular would have no chance for their social development and economic growth. Mobility is therefore necessary. It is crucial how we make it both cost-efficient and sustainable! I think the magic word in this context is green-house-gas (GHG) reduction costs - in other words, how much money do I have to invest in technology to achieve what effect in terms of GHG reduction? So it can be cleverer, especially for the transport sector, to further develop conventional or hybrid powertrain systems and at the same time invest in traffic control and routing rather than only being on the road in the dimension of "zero emissions". But there is no doubt that we need to significantly reduce transport-related emissions - globally. Since 2020, for example, we have been working on highly efficient powertrain technologies for road freight transport as part of a large Fraunhofer project, and in one sub-project we are also looking very explicitly at the situation in developing and emerging countries: For example, we are researching the production of biogas from pig slurry and agricultural by-products and the efficient combustion of this gas in a particularly low-emission engine that is only a fifth of the size of conventional truck engines. This saves significant amounts of CO2 and at the same time even money when operating the vehicle.

Mobility as a basic social need: What offers will there be for this?

It is clear that we will see completely different forms of mobility in the future beyond the classic car. That is perhaps the greatest advantage that electromobility offers to us: The traction drives and storage systems are so scalable that they can be used to equip e-bikes, three-wheelers or even light aircrafts for vertical mobility. Individual mobility will thus become very diverse and certainly be supplemented by offers such as car sharing or car platooning. This is a very good way to address special needs with regard to occasional or permanent vehicle use. The Fraunhofer organisation and the LBF are involved in all these developments and are good innovation partners for companies worldwide. We believe that the transformation of the transport sector, that will take place over the next 20 years, will see many tasks that require strong research organisations and courageous industrial companies.



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Solid-state batteries: Manufacturing of Composite Electrodes and Thin-Film Batteries

Source : Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM

About Fraunhofer IFAM:
Founded in 1968 and integrated into the Fraunhofer-Gesellschaft in 1974, the Fraunhofer IFAM is one of the most important research institutions in Europe for adhesive bonding technology, surfaces, shaping and functional materials. At our institute's five locations – Bremen, Dresden, Stade, Wolfsburg and Braunschweig as well as at the Test Center for Martime Technologies on Helgoland – Fraunhofer IFAM puts its central principles into practice: scientific excellence, a focus on the application of technology, measurable utility for customers while ensuring the highest quality.

Manufacturing of composite electrodes

A main motivation for the development of solid-state batteries, besides the increased energy content, is their intrinsic safety as these contain, in contrast to conventional lithium-ion batteries, no flammable liquid electrolyte. Solid-state electrolytes further possess a high level of electrochemical stability and can thus enable the use of novel high voltage electrodes with a high cycle stability. According to theoretical calculations, specific energies above 400Wh/kg and energy densities of more than 1200 Wh/L are possible.

The scalability and processing of solid-state batteries represents a particular challenge. Hybrid electrolytes made of inorganic materials and polymers offer a material option with a high potential. Hereby, the complex structure of these electrolytes as well as the electrical and the ionic conductivity must be ensured.

One of our focus points is the manufacture of composite cathodes consisting of active material and a solid-state electrolyte, e.g. via inert processing through extrusion. The development and understanding of the individual process steps are hereby particularly in focus.

Thin-film batteries

The low ionic conductivities of potential solid-state electrolytes can be compensated through the minimization of the electrolyte film thickness. The so-called thin-film technology also enables flexible as well as three-dimensional battery geometries. These are particularly of interest for miniaturized applications, but also for component integration as well as for self-sufficient sensor nodes. During the manufacturing of thin-film electrodes and batteries, the so-called PVD technology (physical vapour deposition) comes into play. Hereby, very thin layers are achieved with good phase boundaries for an optimal ionic conductivity.

1. Flexible thin-film electrode, e.g. for solid-state batteries
Image Courtesy: Fraunhofer IFAM

2. Dry processing of composite cathodes
Image Courtesy: Fraunhofer IFAM

Connected Mobility – Vehicle Communication

Source : Fraunhofer Institute for Integrated Circuits IIS

In the field of connected mobility, research and development at Fraunhofer IIS revolves around leading-edge technologies for the intelligent networking of vehicles, using both car-to-car and car-to-environment scenarios. Thus, we are working to enable the implementation of intelligent traffic management systems and autonomous driving. The focus is on efficient mobility: less traffic congestion, increased safety and optimal information provisioning, anywhere and at any time, and thus a higher degree of comfort and streamlined mobility for all traffic participants.

The required underlying technology is based on transmission technologies that provide full-coverage, reliable broadband provisioning for the mobile user, plus intelligent antennas and broadband automotive networks. Our research activities focus on improving communication between the various data sources and processing platforms.

The new technologies will enable the automobile industry, infrastructure operators and service/application providers to design vehicles and traffic concepts for the future.

Intelligent connectivity

The vehicles of the future will communicate continuously with the environment and react independently when danger situations arise. The key to this development is the intelligent networking of vehicles, which are permanently connected to the Internet, with other vehicles, the surrounding environment and satellites via a high-performance air interface.

To prevent this vision from turning into a mere future scenario, Fraunhofer IIS is already deeply involved in the automobile ecosystem of tomorrow. Fraunhofer IIS develops the underlying transmission technologies for various application scenarios and supply data transmission and distribution solutions.

Optimization of the data transmission technologies is achieved by developing reliable wireless and broadcast connections that support the mobile communication applications. To ensure ideal distribution of the data in the vehicle, Fraunhofer IIS has created high-speed bus systems for broadband automotive networks.

Our key issues for connected mobility

- Hybrid network technologies: Merging different wireless technologies and standards to what the user perceives as a transparent communication channel.
- Broadband automotive E/E system concepts: High-speed connectivity for fast and efficient distribution of data in the vehicle.
- Broadband provisioning for the mobile user: Enhancement of communication standards and technologies in order to address the growing demand for mobile data
- New services and applications: Development of initial prototypes for testing and optimization of the new technologies.

1. Communication Technologies for Mobility Networks
Image Courtesy: Fraunhofer IIS

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Dimensioning and simulation tools for the electrification of commercial vehicles - Analyses for the introduction of electric public transport vehicles

Source : Fraunhofer Institute for Transportation and Infrastructure Systems IVI

The Focus Areas include

Electric vehicle fleets; automated simulation processes; modular structure; comparison of concepts; calculation of driving performance and energy requirements; optimization of operational strategies; overall vehicle concept (all types)

IVIsion

IVIsion is used for a rapid comparison of novel propulsion technologies for your vehicle. We will assess the energy flows and determine under which operational conditions your vehicle can function in the best possible way. We will dimension the drivetrain components and auxiliaries according to the planned conditions and application scenarios.

IVInet - Measurement Data Processing:

IVInet includes automated processing of large amounts of data from long-term measurements for simulations (GPS data, CAN data, passenger load). It is applicable for entire public transport networks. The algorithms are specially adapted to scenarios in public transport.

IVImap – Mapping:

With IVImap, image-based maps can be read, scaled and edited. The powertrain maps necessary for simulations are often not available. Therefore, IVImap already contains a large variety of maps of typical components. These maps can be adapted to the exact values of the respective application using IVImap.

IVIdrive - Overall Vehicle Simulation

- **Vehicle model:** It includes more than 100 pre-set vehicle and powertrain configurations. It has up to three segments and five axels. There are map-based models for combustion engines, electric engines and gearboxes. The power electronics are based on characteristic curves. It also has an on-board power supply (high and low voltage), energy storages (batteries, caps), cooling of components, compressed air system, air-conditioning of passenger compartment, tire-road wheel slip model and a user interface for vehicle configuration.

Image Courtesy: Fraunhofer IVI

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- Fields of Application: Calculation of driving performance, energy balancing, dimensioning of components, system optimization and testing of operational strategies. It is Pre-configured and adaptive regarding performance of powertrain. Depending on the type of driver, it is flexible for a characterization of vehicles. It also contains a self-learning SOC control of electric energy storages and intelligent auxiliary management.

Distinctions in Public Transport Simulation

There is a wayside energy supply at stop and while driving. It also takes into consideration the various recharging strategies. There is a high positional accuracy of the simulation (precise halting at stops and recharging points). Also, it maps a high number of different auxiliaries and emission-free traffic zones is considered.

About Fraunhofer Institute for Transportation and Infrastructure Systems:

The Fraunhofer Institute for Transportation and Infrastructure Systems IVI employs over 100 researchers in four departments. The institute collaborates closely with the universities TU Dresden, TU Bergakademie Freiberg and Technische Hochschule Ingolstadt. Its transport-related research work ranges from the field of vehicle and propulsion systems to intelligent transport systems, and it also covers the areas of disposition, logistics and digital business processes.

For more than 20 years, the Fraunhofer IVI has been developing innovations for the intelligent planning, coordination and management of mobility, shaping the digital transformation of public transport with reliable information and assistance systems, platform solutions for mobility data and services as well as electronic ticketing.

The research fields include:

- Civil Protection and Security
- Electromobility
- Energy Systems
- Process Data Analysis
- Intelligent Transport and Mobility Systems
- Vehicle and Propulsion Technologies

1. & 2. With IVIsion and IVInet, entire public transport networks can be simulated
Image Courtesy: Fraunhofer IVI

PV for Mobility: Solar Electricity from the Car Roof

Source : Fraunhofer Institute for Solar Energy Systems ISE

According to current estimates, more than 70 % of all vehicles newly registered in Germany in 2028 will have electric drive units, some of them within hybrid vehicles. Solar cells that are integrated into the vehicle can reduce the external electricity consumption and CO2 emissions considerably and increase the range of electric vehicles noticeably. The prototype of a highly efficient solar car roof that has been developed at Fraunhofer ISE represents a completely new approach, with its curved form and coloured surface. The solar cells used are commercially available PERC solar cells, which today achieve efficiency values exceeding 22 % in series production and are inexpensively available on the market. The solar cells are cut into six strips with a laser process that causes little damage. The strips are laid in rows and each row slightly overlapping the following row, connected by an electrically conductive adhesive (ECA). The rows can also be displaced sideways with respect to each other. In this way, an electrically and mechanically connected matrix is created, with which modules of different dimensions can be covered completely and very flexibly. This so-called matrix shingle process allows for the significant reduction of losses of active area and resistance in a module compared to classic connection processes.

Matrix shingle modules have very high module efficiency, they feature an extremely homogeneous appearance, they show lower power losses under partial shading conditions and the connection is lead-free. In cooperation with materials and equipment producers, Fraunhofer ISE is developing adhesives, processes and equipment for shingle and matrix shingle technology.

For demonstration, a cell assembly based on matrix shingle technology was integrated into a commercially available, panoramic car roof made of curved glass. Already established production technology for car roofs was applied for the process. The MorphoColor® optical structure, which was developed at Fraunhofer ISE, covers the solar cells within the glass laminate and can be produced in many different, highly saturated colours. Compared to an uncoated glass cover, the transmittance loss due to MorphoColor® amounts to only 7 %rel. on average. The combination of commercially available PERC solar cells, matrix shingle technology and the MorphoColor® coating is the ideal basis for cost-effective, aesthetically attractive products for integrated photovoltaics.

The power density of the photovoltaic car roof can reach about 210 W / m2 and, using the typical roof area of a medium-sized car, the modules provide electricity for driving up to 13 km per day. The estimate is based on the solar radiation on a sunny summer day in Freiburg and a vehicle power consumption of 17 kWh per 100 km.

1. Highly efficient but invisible solar cells in the car roof display good performance

2. Vehicle integrated photovoltaics
Image Courtesy: Fraunhofer ISE

1

foxBMS- The Most Advanced Open Source BMS Platform

Source : Fraunhofer Institute for Integrated Systems and Device Technology IISB

After the great success of the first generation of foxBMS, which was the first free, open and flexible research and development environment for the design of complex Battery Management Systems (BMS), Fraunhofer IISB is proud to announce that the second generation of its foxBMS platform, foxBMS 2 version 1.0.0, is available!

Simplicity of foxBMS 2

foxBMS is a free, open and flexible research and development environment to empower everybody to build Battery Management Systems (BMS) beyond state of the art. To live up to this promise Fraunhofer IISB has drastically reduced the complexity of developing on and for the foxBMS platform. One of the obstacles that Fraunhofer identified in foxBMS 1 was the architecture around two physically separated microcontrollers (MCU). The purpose of the combination of both MCUs has been to serve as a safety net during development. In reality, this is raising the software and system complexity, thus becoming a source of human errors. Therefore, Fraunhofer removed the need for a secondary MCU while at the same time streamlining the safety concept by choosing an appropriate safety-qualified MCU providing a dual-core lockstep architecture. Fraunhofer IISB has revised the component selection to only use AEC-Q qualified components. These clever design choices drastically improve the safety and the versatility of the foxBMS platform, enabling it to be used in safety critical automotive, industrial, aerospace, marine and even defence applications.

The configuration features of the software have been extended to describe battery system architectures in an even simpler and more detailed way. The list of software tools that need to be installed has grown slightly. But the improvements gained by this are superb, let's see for example the unit testing feature. You can now unit test large parts of the software inside the IDE without having to develop every part of your next generation state-of-charge (SOC) algorithm in the time consuming code – deploy-to-hardware – debug cycle. By enabling unit tests for foxBMS you can now enjoy much shorter code – deploy-to-hardware – debug cycles. It saves you time, money and for sure some headache while developing your prototype or product.

Safety of foxBMS 2

While foxBMS is intended as a development platform, functional safety is a concern even in early stages of developments in the lab. With the second generation of the platform Fraunhofer has chosen to address this issue specifically and in an innovative way, enabling it to potentially fulfil the safety requirements in multiple application domains based on a single hardware platform.

1. foxBMS Central Control Unit
Image Courtesy: Fraunhofer IISB

Services Fraunhofer IISB offers:
The following list gives an example of services offered in the research and development team at the Fraunhofer IISB:

- Manufacturing and shipment of foxBMS development kits and customized prototypes
- Design of electronic BMS hardware and optimization for your specific requirements
- Development of embedded BMS software and configuration for your specific application
- Modelling of battery cells (electric and thermal) for accurate state estimation algorithms (e.g., SOC, SOE, SOH, SOP)
- Prototyping of high performance battery systems (e.g., for automotive, aviation and stationary applications)
- Consulting in the field of battery systems and failure analysis

A critical step while developing the safety concept is the choice of the MCU. Fraunhofer has chosen the Texas Instruments TMS570LC4357 for foxBMS 2. The TMS570LC4357 is an ARM Cortex-R5F safety MCU and uses a dual-core lockstep architecture. It provides extensive diagnostic features, such as a Built-In Self-Test (BIST) logic for the CPU and an Error Correction Code (ECC) protection for the internal buses, caches, flash and SRAM memories.

Functional Safety is a process that ensures that the developed system fulfils its tasks with certainty so that neither persons nor the surroundings are harmed. This always has to be tailored to a specific use case and development cycle. Therefore, it is not possible to have a one-size-fits-all BMS that magically fulfils all possible functional safety requirements at once. However, Fraunhofer has done the important groundwork to enable functional safety development processes. The components have been carefully chosen for parts with known reliability and high diagnostic coverage. For all the major components Fraunhofer is in contact with its manufacturers in order to be able to support the industry development process. With foxBMS 2 and its focus on a clean safety concept, we enable the development of safe and reliable BMS for nearly all kinds of battery systems in mobile and stationary applications!

Connectivity and Algorithm Development

One key in making high-quality battery systems is accurate battery state estimation algorithms (Sox), where x is charge, energy, power, health, life or safety and transferring this knowledge into optimized operating strategies for the specific application.foxBMS 2 provides an interface to bring these algorithms in a simple way into your application. One of the blog entries will cover the deployment of algorithms to the application. In order to enable this, we will also extend our focus to the connectivity of the BMS.

Improved connectivity allows to grow the applications around the BMS. Internet of Things (IoT) applications allow the aggregation of battery data. This can scale from the monitoring of single battery systems to big data applications. We are working on employing advanced artificial intelligence (AI) methods for generating deep insights into the captured data. Benefits of AI can be improved state estimation of the system, more economic usage of batteries or increased confidence in the stability of a system.

2.
Image Courtesy: Fraunhofer IISB

An interview with
Mr. Sunjay Kapur
Chairman, SONA-COMSTAR and President, ACMA

Mr Sunjay Kapur is the President of ACMA and also the Chairman at SONA-COMSTAR Pvt.Ltd.
Mr. Kapur is an industry expert on one of the leading auto components manufacturers and has a deep understanding of the auto industry, especially the components segment.

1. As a newly elected President of ACMA, how do you reimagine the development of EV sector from a system engineering point of view—Both design of brand-new platforms and adapting existing platforms?

At ACMA, we have set a target for tripling the auto components exports from India to USD 45 billion in next 5 years. With steady economic recovery, consumer sentiment seems to be fast improving, and demand is returning in the automotive sector. In tandem with the set objectives of the PLI scheme, the way forward is to ensure that products that are made in India are price competitive on a global platform. It is also to warrant that the steps in the direction of the EV boost in the country do not lose momentum. There is one answer with regard to the development of EV— Investment in technology. Technology is the way forward if we want to scale new heights. Adapting and actualizing the technology in our manufacturing prowess will lead to successful synchronisation on existing platforms and ascertain the new integrations ahead of us.

2. Will PLI Scheme for Automobile & Auto components be a catalyst for driving the future of Mobility and Transportation in India?

The Government's production-linked incentive (PLI) scheme is a definite step towards augmentation of the sector. In accordance with our national priorities of energy security and climate change, the PLI scheme envisions creation of an 'Atmanirbhar' (self-reliant) Bharat that is globally competitive with a future-ready automotive sector. Moreover, the scheme is encouraging non-automotive companies to participate and therefore, it is a new revenue avenue for new entrants to venture into the automobile and auto component segments. PLI will play catalyst to a vibrant ecosystem for manufacturing of automotive parts. It is expected to attract fresh investments, facilitate efficiencies, and instill healthy competition. Not to mention, a substantial increase in direct and indirect employment opportunities in India, and it is also expected to boost exports. For this reason alone, the scheme looks promising.

3. What are your views for Indian Auto component manufacturers in order to build a robust autonomy for next gen technologies when the internet meets the car?

The internet has already met the car. Most auto-OEMs today offer connected services driven by customer demand for advanced features, regulations and improvement in cellular services. Remote services, over-the-air (OTA) updates and advanced diagnostics are only expected to grow with the advent of 5G. However, connected cars are vulnerable to cyberattacks originating from multiple sources—the internet itself and direct ECU attacks through OBD ports, GPS or Radar sensors, or near-field networks such as Bluetooth and Wi-Fi. The challenge of cyber security offers a host of opportunities for auto-component manufacturers as they can partner with OEMs and service providers to create products to aid the secure processing of data and create secure networks, gateways, and interfaces. Indian auto component makers will have to build competencies in advanced electrical/electronic architectures and cutting-edge software in order to keep pure software companies, tech companies, semiconductor makers and electronics manufacturing services (EMS) companies from posing serious competitive threats.

4. How is SONA Group future gazing its road map for next generation EV segment — What can we expect?

The next-generation EVs will be more efficient, robust, and affordable. The software will play a significant role in their functioning. The powertrains of future electric vehicles will be power-dense and highly efficient. Sona-Comstar's technology road map aims to follow this path. We are working on integrated drive units that offer our customers efficiency, compactness, and cost advantage. We are working on motors that do not use rare earth magnets, inverters that have state-of-the-art software under their hoods, offering the best experience to the occupants of the vehicles and multiple technology dimensions from materials science, mechanical, electrical, electronics, and software engineering to enhance user experience.

1

The role of Hydrogen in future technologies

Source : Fraunhofer Institute for Solar Energy Systems ISE

Hydrogen technologies have an increasingly important role to play in industry's transition toward sustainable value creation. They form a key part of strategic plans to safeguard a sustainable future. Fraunhofer's expertise includes materials, systems and their production and use in industry, mobility and the energy sector. It also covers interdisciplinary topics such as security and service life. The market for hydrogen technology is only just beginning to ramp up worldwide. When it comes to putting hydrogen technologies into practice, government and industry rely on Fraunhofer as a key strategic partner. Fraunhofer experts have spent many years applying their expertise in this pivotal research field in numerous successful projects. Their skills help drive forward and commercialize scientific solutions.

Climate-neutral industrial processes

Companies are now making big efforts to switch established production processes over to hydrogen and to work toward the creation of a hydrogen economy in the long term. One promising area for the use of hydrogen is in production processes that generate large volumes of carbon dioxide. Here, hydrogen offers various ways of de-fossilizing the production chain. The key task is to make this switch both economical and sustainable.

Balancing the energy system

With the help of Hydrogen Technology, electricity generated from renewable sources is used to power a process of electrolysis, which splits water electrochemically into hydrogen and oxygen – a form in which this energy becomes storable and transportable. The hydrogen produced in this way can then be converted back into electricity. This green hydrogen serves to increase the security of supply and grid resilience.

Transport without fossil fuels

The goal is for the transport sector to forgo fossil fuels altogether. Hydrogen-powered propulsion systems can complement this technology. Hydrogen is either used to power a combustion engine or converted into electricity via a fuel cell. Hydrogen vehicles possess a number of advantages over electric vehicles.

Safety and reliability: Standards, testing, life cycle analysis

Hydrogen has a huge potential as an energy carrier. However, its use requires strict safety precautions. It is therefore vital to ensure proper test procedures for the materials and components of fuel cells and electrolysis cells. Closely related to safety is the question of service life. Fraunhofer Institutes run numerous projects that address these aspects, complete with the relevant test rigs.

2. Perspectives H2 – how to stay mobile
Hydrogen – a source of energy and a source of hope
Image Courtesy: Fraunhofer ISE

2

From material to system: The technical basis

As an energy carrier and chemical feedstock, hydrogen is destined to play a key role in helping us meet climate targets. For this to occur, the systems for generating, storing, transporting and using hydrogen must become more efficient, economic as well as safer and robust. With all the expertise it has to offer, Fraunhofer will play a key role here.

System production: Scaling up volume and size

The use of renewable energy and hydrogen is significantly expanding. The installed capacity for electrolysis is assumed to reach around 1 gigawatt by 2022, rising by a factor of 200 over the period to 2050. This would entail an average increase in capacity of between 4 and 8 gigawatts per year.

Members of the Fraunhofer Hydrogen Network

- Fraunhofer Institute for Building Physics IBP
- Fraunhofer Institute for Chemical Technology ICT
- Fraunhofer Institute for Ceramic Technologies and Systems IKTS
- Fraunhofer Institute for Energy Economics and Energy System Technology IEE
- Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT
- Fraunhofer Institute for Factory Operation and Automation IFF
- Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI
- Fraunhofer Institute for Industrial Engineering IAO
- Fraunhofer Institute for Integrated Systems and Device Technology IISB
- Fraunhofer Institute for Laser Technology ILT
- Fraunhofer Institute for Machine Tools and Forming Technology IWU
- Fraunhofer Institute for Manufacturing Engineering and Automation IPA
- Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM
- Fraunhofer Institute for Material and Beam Technology IWS
- Fraunhofer Institute for Mechanics of Materials IWM
- Fraunhofer Institute for Microelectronic Circuits and Systems IMS
- Fraunhofer Institute for Microengineering and Microsystems IMM
- Fraunhofer Institute for Microstructure of Materials and Systems IMWS
- Fraunhofer Institute for Nondestructive Testing IZFP
- Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP
- Fraunhofer Institute for Physical Measurement Techniques IPM
- Fraunhofer Institute for Production Technology IPT
- Fraunhofer Institute for Solar Energy Systems ISE
- Fraunhofer Institute for Surface Engineering and Thin Films IST
- Fraunhofer Institute for Systems and Innovation Research ISI
- Fraunhofer Institute for Wind Energy Systems
- Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG
- Fraunhofer Institute for Applied Polymer Research IAP
- Fraunhofer Institute for Structural Durability and System Reliability LBF
- Fraunhofer Institute for Integrated Circuits IIS
- Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB
- Fraunhofer Research Institution for Materials Recycling and Resource Strategies IWKS
- Fraunhofer Center for International Management and Knowledge Economy IMW

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Hydrogen Technologies and Electrical Energy Storage

Source : Fraunhofer Institute for Solar Energy Systems ISE

Hydrogen Technologies

Fraunhofer ISE conducts research on the production, conversion and further thermochemical processing of hydrogen. In the context of the increasing importance of green hydrogen as a fuel, it led the work on the Fraunhofer Hydrogen Roadmap last year and surveyed the potential in the region within the project "H2-SO – Hydrogen Technologies in the Southern Upper Rhine". With regard to hydrogen production, Fraunhofer ISE is concentrating on polymer-electrolyte membrane electrolysis (PEM). Fraunhofer ISE also applies PEM technology to develop fuel cell systems, particularly for the mobility sector. In the "HyFab" project, they are investigating automated production and quality control processes for the industrial production of fuel cells.

Based on thermo-chemical processes, liquid fuels and chemicals are synthesized from hydrogen and carbon dioxide (power-to-liquids). One example is the new miniature plant for methanol synthesis.

Electrical Energy Storage

For battery materials, cells, modules and systems, new material combinations, cell architecture and manufacturing processes, construction and interconnection technology, formation, aging and characterization are investigated. The laboratory is a part of the "Development and test center for batteries and energy storage systems" in the Haidhaus in Freiburg, which is supported by the State Ministry for Economics, Labor and Housing in Baden-Württemberg and the BMBF. Fraunhofer ISE also develops complete prototypes and accompany their partners with integration into extremely diverse applications and the corresponding quality assurance. Examples include stationary battery storage units, which are used commercially or industrially, as well as applications for electromobility, covering the whole range up to the electrification or hybridization of ships.

In the Business Area Hydrogen Technologies, Fraunhofer ISE's work focuses on the following research topics:

- Thermochemical Processes
- Fuel cell systems
- Electrolysis and Power-to-Gas
- Applied Storage Systems
- Battery System Technology
- Battery Cell Technology

1. Battery Cell Development - Assembling a button cell
Image Courtesy: Fraunhofer ISE

Power-To-Gas and Hydrogen Infrastructure

Source : Fraunhofer Institute for Solar Energy Systems ISE

Fraunhofer ISE offers a wide range of R&D services in the fields of PtG, hydrogen mobility and hydrogen infrastructure:

- Feasibility analyses, technology and market studies
- Plant design and conception
- Techno-economic analysis and optimization of the plants
- Assessment of plant locations & logistics
- Bankable hydrogen yield forecasts
- Life Cycle Assessment (LCA)
- Consideration or in-depth analysis of Power-to-X, photovoltaics, heat utilization, etc. as part of the hydrogen plant
- Development and live testing of operating strategies
- Component testing for hydrogen mobility and hydrogen/natural gas networks
- Plant monitoring during operation
- Support in the planning and construction phase

The term Power-to-Gas (PtG) describes the conversion of electrical energy (power) into chemical energy (gas) via water electrolysis. The produced hydrogen gas can be used both energetically (e.g. as fuel) and as a feedstock (e.g. in industry). Also the configuration of PtG plants has to be optimized in order to operate them economically. However, the coupling of PtG plants with renewable energy sources and users of the generated hydrogen is complex. Also the connection to different sectors of the energy system and the necessary further processing have to be considered carefully in order to operate PtG plants economically. Significant aspects in the techno-economic evaluation of the plants are the interaction of the individual components with each other, the respective business and operating model, as well as the associated hydrogen logistics (trailers, pipelines).

Evaluation of PtG plants, hydrogen refuelling stations and H2 infrastructure

The toolbox "H2ProSim" developed at Fraunhofer ISE is an extensive tool for the simulation-based, techno-economic evaluation of hydrogen plants and business models. The different plant components are modeled using the simulation environment "Matlab/Simulink/Stateflow". The toolbox enables:

- Cost-efficient and flexible analysis of various plant configurations
- Dynamic modeling of technical plant operation
- Consideration of integration into the higher-level energy system and into markets through market participation modelling, portfolio operation or time series

Features of "H2ProSim":

- Modular structure and continuous further development
- High accuracy thanks to comprehensive validation, even on our self-operated demo systems
- Technical management via separate model level
- Integrated cost model for the calculation of hydrogen production costs (LCOHy)

The "H2ProSim" toolbox can be used to answer a wide range of questions on hydrogen plants. Examples are:

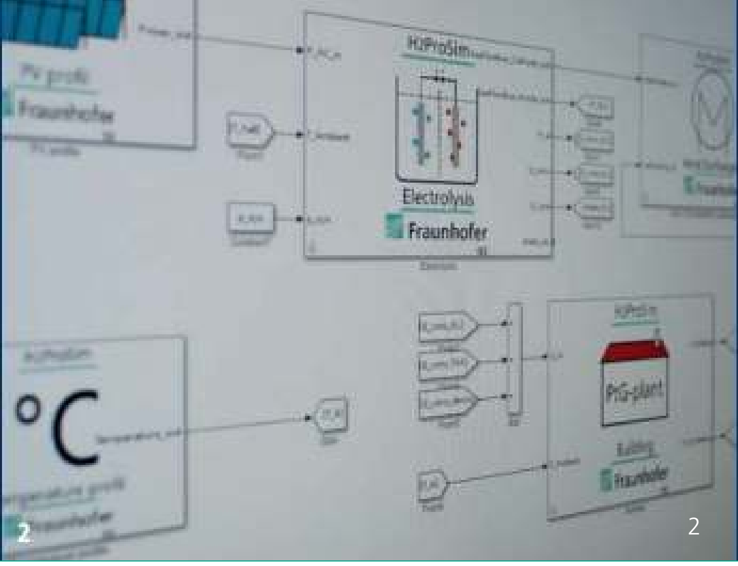
Feasibility analyses

With the help of standard models and parameters, Fraunhofer ISE is able to quickly and cost-efficiently estimate the production costs and economic efficiency of a business idea. The model can also be used to easily analyze different scenarios and variations of the business models.

Plant design and optimization

With more in-depth modeling, a plant design can be developed up to the rough concept and

Fraunhofer ISE's solar hydrogen filling station is a platform for scientific research and component testing
Image Courtesy: Fraunhofer ISE



optimized techno economically. Typical examples are the effects of different electrolyzer types and locations on the operating behaviour of the PtG plant, OPEX minimization, possibilities of heat extraction or oxygen utilization as well as the integration of electricity storage facilities. The optimization framework allows selected parameters of the plant to be optimized for specific techno-economic targets.

Yield forecasts

Hydrogen yield forecasts for submission to lenders can be made for existing plant concepts and locations.

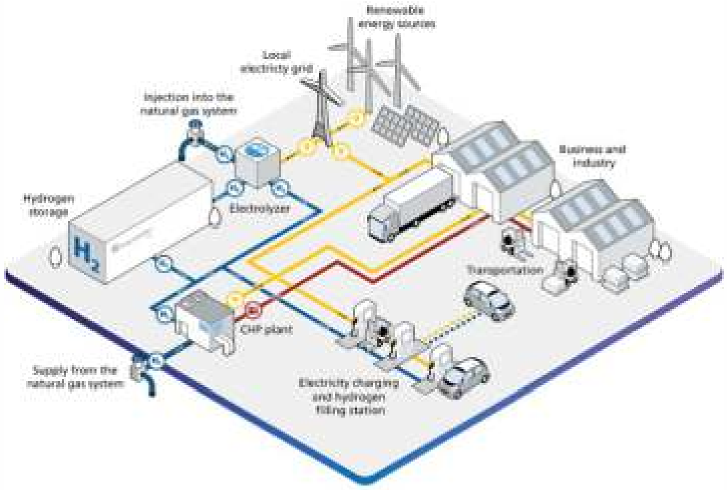
Component tests and development of operational management

Fraunhofer ISE is operating a hydrogen filling station since 2012 and a hydrogen feed-in plant since 2017 as part of the respective public infrastructure. Due to the open interfaces and the operation as a research platform, component tests can be carried out at these plants under real conditions. Fraunhofer ISE also develops operational management strategies and test them in real operation. Targeted measurement programs are also possible.

Due to the continuous operation of these plants in the real environment, the institute has a broad database and many years of experience in the construction and operation of hydrogen plants.

2. Structure of thesimulation toolbox "H2ProSim" withcomponent-based modeling for the techno-economic evaluation of hydrogen refueling stations, Power-to-Hydrogen and Power-to-Xplants.
Image Courtesy: Fraunhofer ISE

3. Acquisition of measurement data for validation of the simulation toolbox at the in-house hydrogen feed-in plant
Image Courtesy: Fraunhofer ISE



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The hydrogen factory of the future
Image Courtesy: Fraunhofer IFF

The hydrogen factory of the future

Source : Fraunhofer Institute for Factory Operation and Automation IFF

The Fraunhofer IFF is working together with MicroPro GmbH and Streicher Anlagenbau GmbH & Co. KG in the HyPerFerMent I project to produce renewable hydrogen from biomass. They are employing a special microbial fermentation process similar to biogas production to produce hydrogen directly from organic waste. The metabolites of certain bacteria produce a gas mixture containing CO2 and fifty percent H2, which can be easily purified by subsequently separating the CO2. “Fermentative production of green hydrogen will play a major role in distributed production of this energy carrier in the future,” says Birth.

Hydrogen is indispensable to successfully transitioning to renewables and meeting climate targets. It is the essential building block of sector coupling. While it provides an eco-friendly option to meet industry demand for electricity, heat and transportation, this versatile energy source is only eco-friendly when it is sourced from renewables. The Fraunhofer Institute for Factory Operation and Automation IFF has a demand-driven, distributed, modular solution that produces and distributes green hydrogen.

The only way to contain global warming is to slash greenhouse gas emissions on a global scale. Power-to-X technologies are considered a promising means to this end: for instance, electricity sourced from renewables is converted into hydrogen to power fuel cell vehicles. Researchers at the Fraunhofer IFF in Magdeburg are taking this a step further. They are establishing a design for the distributed and modular production and distribution of green hydrogen for industry, business and transportation throughout the value chain with their hydrogen factory of the future. “Electricity sourced from sun and wind is used to split water into hydrogen and oxygen in a process called electrolysis. The hydrogen is stored and converted by fuel cells in vehicles back into electricity that powers them. Fraunhofer IFF primarily has vehicle fleets with vans and forklifts operating in industrial and business parks in mind here,” says Dr. Torsten Birth, a research scientist at Fraunhofer IFF. “We additionally want to supply electricity, gas and heat to industry. The hydrogen produced during electrolysis can be injected into the gas grid, used as fuel, converted into methane or methanol, and made available as industrial feedstock.”

Coupling hydrogen production into a biogas plant

The research scientists are developing modularly expandable subcomponents that can be interconnected and integrated in business and industrial parks, which will enable them to implement their hydrogen factory design. Electrochemical or biochemical processes are used to produce hydrogen, depending on the conditions at the site. “It is not possible to build wind and PV plants everywhere. Fraunhofer IFF is opting for site-specific solutions and using biogas plants for production where possible. Plans for a pilot plant near Gommern in Saxony-Anhalt are on the drawing board. The outcome is always green hydrogen,” the engineer Birth explains.

A mobile hydrogen filling station for industrial and commercial parks

Researchers at the Fraunhofer IFF have teamed up with Anleg GmbH to build one of the aforementioned subcomponents, the Mobile Modular H2 Port (MMH2P), a portable hydrogen filling station for short trips of up to 200 kilometers. Expandable pressure systems with compressors on a trailer can be refilled and can dispense hydrogen. The German Federal Ministry of Education and Research (BMBF) is funding the project.

Disinfecting with ozone

Since systemically integrated hydrogen production is important to the researchers, they will not only be using the hydrogen produced during electrolysis but also the oxygen – for welding processes or for ozonation in sewage treatment plants, for instance. Troublesome micro pollutants such as pharmaceuticals, pesticides and cosmetics can be removed from wastewater when ozone is introduced. Another use scenario envisions using the oxygen in agriculture to desulfurize biogas plants.

The research team acquired expertise for the implementation of their hydrogen factory in the projects Energieregion Stassfurt 2020 and Energieregion Ostharz. A regional energy plan was implemented in these projects to switch the energy supply in different sectors (power, gas, heat, and transportation) from fossil fuels to regionally produced renewables and renewable sector coupling systems were developed.

2. Fraunhofer researchers intend to produce hydrogen in biogas plants too
Image Courtesy: Fraunhofer IFF

Germany already has one of the best networks of H_2 filling stations

An interview with **Prof. Dr. Christopher Hebling,**

Division Director of Hydrogen Technologies at Fraunhofer ISE and spokesperson of the Fraunhofer Hydrogen Network

There are still only a couple of hundred H2 -powered cars on German roads, but this will have to change fast if federal government is to meet its climate targets.

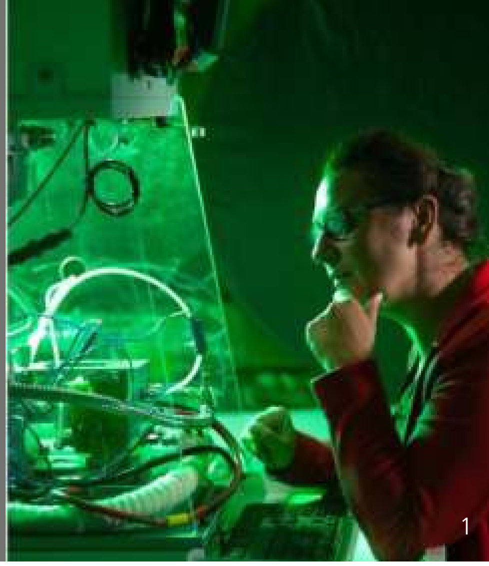
If future transport is to be run largely on hydrogen, then certain preparations must be made now. This means enhancing the technology, especially fuel cells and electrolyzers, establishing technical and industrial standards, and expanding the infrastructure for distribution and refueling. Fraunhofer researchers are currently involved in a host of projects to promote hydrogen technology and support the industry.

What can hydrogen bring to future transport?

Hydrogen still plays a minor role in the transport sector. Despite the low number of hydrogen cars, Germany's position regarding hydrogen technology is not too bad. "We already have one of the best networks of hydrogen stations," explains Prof. Christopher Hebling, Division Director of Hydrogen Technologies at the Fraunhofer Institute for Solar Energy Systems ISE and spokesperson of the Fraunhofer Hydrogen Network. "And there are plans to expand from 100 to 400 stations over the next three years." It makes good sense primarily to use hydrogen where longer distances are involved – heavy goods transport, for example, inland shipping, and rail transport on branch lines that have not yet been electrified. As with electric vehicles, green electricity – in other words, electricity generated from renewable energy sources such as wind and sun – can be used to produce hydrogen that is then utilized to power vehicles on a local and carbon-free basis.

If future transport is to be run largely on hydrogen, then certain preparations must be made now. This means enhancing the technology, especially fuel cells and electrolyzers, establishing technical and industrial standards, and expanding the infrastructure for distribution and refueling. Fraunhofer researchers are currently involved in a host of projects to promote hydrogen technology and support the industry. At the same time, the Fraunhofer-Gesellschaft is providing government with expert consultation. For example, Fraunhofer has recently published A Hydrogen Roadmap for Germany, which sets out its own scientific position regarding hydrogen electrolysis and hydrogen use. This report has also been made available to the federal chancellery and to federal ministries that worked on the development of the National Hydrogen Strategy.

The Fraunhofer H2D initiative creates an overarching strategy that pulls together various institutes and specific expertise. H2D is also intended to provide inspiration for people in government, business and society. The Fraunhofer Hydrogen Network, meanwhile, was established to simplify the sharing of expertise in the field of hydrogen technology. All in all, a total of 28 Fraunhofer institutes are now using the network to swap information and coordinate collaboration. At the same time, a number of hydrogen alliances have formed on the regional level. These include the H2 – Innovationslabor Heilbronn-Franken, a project which aims to turn the Heilbronn-Franken region into a pilot area for the development of hydrogen-related concepts – and which involves the participation of various scientific institutions as well as the Research and Innovation Center for Cognitive Service Systems KODIS, a branch of the Fraunhofer Institute for Industrial Engineering IAO. A further initiative is the HZwo innovation cluster, which aims to bolster, at three different locations, Saxony's



research expertise in fuel cell technology, high-temperature electrolysis and other areas of hydrogen technology.

In 2015, we had 21 megawatts of installed capacity for electrolysis," explains Prof. Ralf B. Wehrspohn, Executive Vice President, Technology Marketing and Business Models, at the Fraunhofer-Gesellschaft. "By 2050, we will need 3000 times that, though not all of it for transport.

How can sufficient (green) hydrogen be produced?

One problem hindering the advent of hydrogen-powered transport is a bottleneck in H2 production. This therefore requires substantial expansion. "In 2015, we had 21 megawatts of installed capacity for electrolysis," explains Prof. Ralf B. Wehrspohn, Executive Vice President, Technology Marketing and Business Models, at the Fraunhofer-Gesellschaft. "By 2050, we will need 3000 times that, though not all of it for transport. In other words, we need to have capacity growth of between 1 and 5 gigawatts a year by 2030." At present, the electrolyzers – which use electricity to generate hydrogen – are still produced largely by hand. To be able to produce this equipment in the requisite volume and with the requisite capacity, system reliability must be improved and suitable production technologies developed. This means automating the production of such equipment, upscaling production to an industrial level and thereby reducing production costs. Fraunhofer ISE, for example, is currently investigating how to reduce the costs of building electrolyzers. Here, researchers are developing new membrane materials, working to extend cell lifetime with an anticorrosion coating, and running endurance trials to test durability. Meanwhile, fellow researchers at the Fraunhofer Institute for Ceramic Technologies and Systems IKTS are combining high-temperature electrolysis with the Fischer-Tropsch Synthesis – an industrial process for coal liquefaction. This pilot plant is to be installed at a lime works belonging to the company Johann Bergmann. It will initially upscale to 10 kilowatts and then provide the basis for further upscaling.

Has the fuel cell drive achieved technological maturity?

Among hydrogen-powered drive systems, the fuel cell is the most familiar. All of the H2 - powered cars currently on the market are equipped with this type of drive: The Toyota Mirai, Hyundai NEXO, Hyundai ix35 FCEV and Mercedes-Benz GLC. Technologically speaking, the fuel cell reverses the process of electrolysis: hydrogen reacts with oxygen to form water, thereby producing electrical energy, which is then used to drive an electric motor. As in the case of electrolyzers, fuel cells are still largely manufactured by hand. However, if fuel cells are to become a standard feature of automotive engineering, an inexpensive method of production is required.

Each car requires much more than just a single fuel cell. A 100-kilowatt vehicle, for example, is equipped with a stack of 400 fuel cells. Given that each day, anything between 1000 and 1500 cars roll off the assembly line in a single automobile plant, it is evident that the scale of fuel cell production must enter a whole new dimension. In terms of cost, too, mass production is vital, as it is only in excess of around 100,000 stacks a year that production for a high-volume use in automobile manufacture will become cost-effective. For this, however, a large number of unresolved production issues must still be determined. This is one of the tasks that Fraunhofer Institute for Production Technology IPT is currently facing. "We are creating a research infrastructure that will enable us to run through the entire production

1. Schattauer inspects a mini electrolyzer installed in the lab of Fraunhofer IMWS

A hydrogen-powered combustion engine burns an ignitable mixture of hydrogen and air in the combustion chamber. What makes this type of engine interesting is not least the fact that it can be modified – by adapting the relevant components – to operate as a bivalent engine that can be run on either hydrogen or a carbon-neutral gasoline fuel.

process on an industrial level," says Dr. Christoph Baum, Managing Chief Engineer of Fraunhofer IPT.

This will replicate the production process in such a way as to eliminate upscaling risks at each of the individual stages of production." When it comes to solid oxide fuel cells, there are various cost drivers. These include manual fabrication and the use of parts made of expensive materials, such as ceramic components in the supply lines. However, researchers at the Fraunhofer Institute for Mechanics of Materials IWM have now discovered a way of coating steel that increases its resistance to hydrogen, compared to non-coated steel, by a factor of around 3500.

What are the alternative H_2 -powered drives for vehicles?

Although the fuel cell offers the most familiar way of exploiting the chemical energy stored in hydrogen, it also has some fairly serious competitors. One of these is the combustion engine, which offers great flexibility in terms of the fuel on which it can run.

The direct combustion of hydrogen is one of the areas of interest at Fraunhofer ICT. Here, researchers are developing and refining combustion processes and related technology in a program that combines computer simulation and concrete experimentation with single-cylinder research engines. Hydrogen has superb combustion properties, meaning that an internal combustion engine can be run on a very lean mixture of hydrogen and air. As a result, only low levels of nitrogen oxides are produced within the engine, and these can be reduced to almost zero by means of simplified exhaust gas treatment. Furthermore, unlike conventional combustion engines, hydrogen engines do not produce any carbon-based emissions, which otherwise necessitate the use of increasingly sophisticated methods of exhaust gas treatment.

Hydrogen-based liquid fuels are also in competition with the fuel cell. The basic concept is simple: green hydrogen generated via electrolysis is combined with carbon dioxide or nitrogen – rather than being turned back into electricity via a fuel cell. The result is methanol ($CH_4 O$), which in turn can be used to produce highly synthesized fuels – more precisely, oxymethylene ethers, which, similar to E10 in gasoline, can be used directly as a diesel substitute. This type of power-to-liquid (PtL) process makes sense primarily in areas where a rapid renewal of vehicle fleets is impracticable or where the conversion of existing infrastructure is prohibitively expensive. Indeed, one of the key advantages of this type of drive is that, in ideal circumstances, no changes must be made to the engine technology – and yet, compared to fossil fuels, greenhouse gas emissions are reduced by as much as 90 percent over the entire functional chain.

Is hydrogen also suitable for powering trucks, ships, trains and aircrafts?

Far less ideological is the question as to whether fuel cells or liquid fuels are better for propelling ships, trucks and aircrafts. In this instance, liquid fuels have clear advantages,

thanks to their high energy density. After all, every ounce of weight counts, especially in aviation, where high performance over long operating times is a necessity. “At Fraunhofer ISE, we’re looking at six alternative processes and evaluating them in terms of, for example, cost and carbon footprint,” says Dr. Achim Schaadt, head of department at Fraunhofer ISE. Vital to this work is a process simulation platform developed by the research team. This helps to identify the kind of process that would be required to produce a million metric tons of fuel a year. “There’s an interplay here between simulation and experimentation: we learn from the results achieved with small- scale plants and then feed these results into our simulation model,” explains Dr. Ouda Salem, head of the Power-to-Liquids group at Fraunhofer ISE. Another project partner is constructing a modular system with an output of 1 kilogram of OME an hour, while others are busy running engine tests. Incidentally, OMEs can be used not only as fuels but also as highly selective green solvents and CO2 sorbents.

PowerPaste is a solid fuel based on magnesium hydride. Instead of heading to the filling station, motorcyclists simply have to replace an empty PowerPaste cartridge with a new one and then top up a tank with water. “PowerPaste stores hydrogen in a chemical form at room temperature and atmospheric pressure,” explains Dr. Marcus Vogt, research associate at Fraunhofer IFAM.

And what about small vehicles such as motorcycles?

When it comes to hydrogen, a special approach is required for small vehicles such as motorcycles. After all, they can’t simply roll up to the hydrogen station and fill up with gas – the pressure on the fuel tank would be too great. Besides, it would be impossible to achieve the required storage density by means of a high-pressure tank small enough to be fitted on a motorcycle. Now, however, a new development from Fraunhofer IFAM in Dresden aims to cater to such applications.

Were a motorcycle to stand for hours in the baking sun, there would still be no danger, since PowerPaste only begins to decompose at temperatures of around 250°C. In fact, PowerPaste would also be an option for larger vehicles, especially where there is a lack of infrastructure in the form of hydrogen stations. After the cartridge is inserted, a plunger forces out the PowerPaste in the precise quantity required by the fuel cell. Water from an on-board tank is then added, and the ensuing reaction produces hydrogen. As with the HyMethShip propulsion system, half of the hydrogen produced comes from the added water.

“PowerPaste has an enormous energy storage density,” says Vogt. “It is substantially higher than that of a high-pressure tank designed to withstand 700 bar. And compared to batteries, it has ten times the energy storage density.” Fraunhofer IFAM is currently building a production plant for PowerPaste at the Fraunhofer Project Center for Energy Storage and Management Systems ZESS. This new facility will be able to produce up to four metric tons of PowerPaste a year – not only for motorcycles.

How can hydrogen be safely transported and supplied at filling stations?

At present, the hydrogen is stored in pressurized tanks. Yet there are drawbacks with this method. For example, it requires the use of elaborate pressurizing and cooling systems. Here, too, an alternative is to use liquid organic hydrogen carriers. LOHCs make it possible to safely transport and store – at no loss – this otherwise highly explosive gas. Researchers at

2. Dr. Marcus Vogt from Fraunhofer IFAM: PowerPaste means that hydrogen vehicles can refuel in areas lacking in infrastructure.

Fraunhofer IAO have integrated Europe's first LOHC storage unit of the latest generation, with a storage capacity of 2000 kilowatt-hours, into the Micro Smart Grid at the Fraunhofer Institute Center in Stuttgart. As for the question of how to use LOHCs for refuelling purposes, the requisite technology is currently being developed by researchers at Fraunhofer HHI, as part of the LOReley project. Funded by the German Federal Ministry for Economic Affairs and Energy, this focuses on the high-capacity production of hydrogen by LOHC reactors equipped with efficient surface catalysts. The key component of the project is the reactor, which is currently under development by researchers. Designed for vehicle-refuelling purposes, this will efficiently extract hydrogen from a carrier oil at a continuous output – in terms of the amount of hydrogen produced – of at least 1 kilowatt and a peak output of 5 kilowatts. In other words, reactor modules should have a simple design, be of compact dimensions and combinable in modular fashion up to the required performance category, and yet still provide formerly unattainable space-time yields. This is enabled by laser-textured reactor plates, as developed by Fraunhofer HHI, which substantially enhance reaction efficiency. This kind of LOHC refuelling station can also be designed as a mobile application. In this case, the LOHC will be stored and transported in a tank truck, along with a mobile reactor.

Hydrogen separation from natural gas with carbon membranes

Source : Fraunhofer Institute for Ceramic Technologies and Systems IKTS

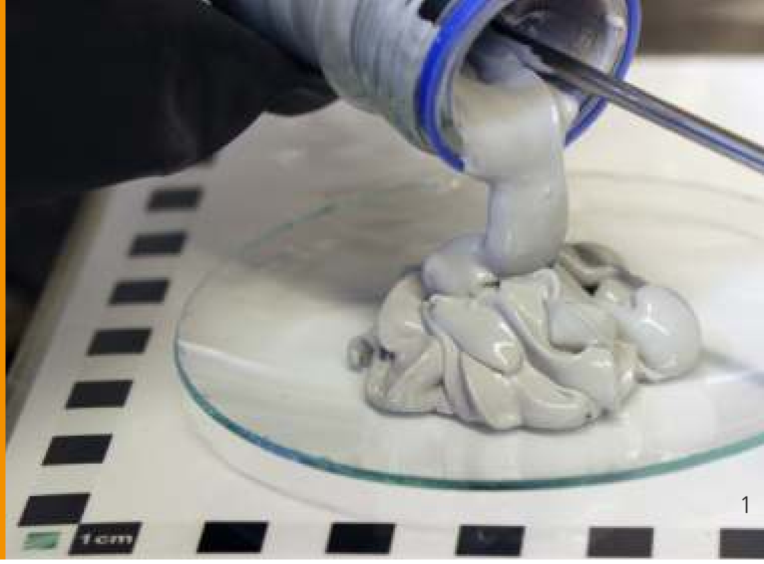
Carbon membranes as separation technology for H2/natural gas mixtures

A main issue in achieving the switch from fossil fuels to renewable energies is the limited availability of renewable electricity due to its dependency on the weather. This challenge has led to numerous concepts aimed at converting power via power-to-gas technologies. Yet, none of the innovative technological approaches has so far passed the threshold of economic efficiency. One reason for this is the absence of a distribution grid. The project HYPOS (Hydrogen Power Storage & Solutions East Germany) aims to connect the chemical power grid, the natural gas grid and the electrical grids in East Germany to provide cost-efficient "green" hydrogen. It has been the general consensus that no separate infrastructure for the storage and distribution of hydrogen will be established in Germany for the foreseeable future. Therefore, one will need to make use of the existing natural gas grid for the production and storage of hydrogen. However, certain applications such as the use of fuel, the concentration of hydrogen in the natural gas grid must not exceed a certain threshold. To use that infrastructure, separating both components (hydrogen and natural gas) before redelivery would be an option: shared storage, separate use. The separation of both components can be realized efficiently by using carbon-based membranes developed at Fraunhofer IKTS in collaboration with project partner DBI-GUT GmbH. The basis for the synthesis of carbon membranes is a suitable precursor. The precursor is applied on an asymmetric porous, ceramic substrate in single-channel geometry. In the next step, the precursor is converted to carbon species with defined properties during a thermal treatment process. The layer thickness of carbon membranes is typically between 250 nm and 1 µm depending on the synthesis procedure and is characterized by an excellent separation behaviour of H2/CH4, with ideal permselectivities of 300. The best membranes were able to concentrate 5 vol % hydrogen in the feed up to 80 vol % in the permeate. In a second separation step, more than 90 vol % hydrogen can be reached in the permeate. Additionally, it has been experimentally proven that the small amounts of water and hydrogen sulfide in the natural gas do not have any significant influence on the separation performance of the membrane. In the research project, carbon membranes were successfully scaled to industry-relevant 600 mm long 19-channel tube substrates.

About Fraunhofer IKTS:

The Fraunhofer Institute for Ceramic Technologies and Systems IKTS covers the field of advanced ceramics from basic preliminary research through to the entire range of applications. Superbly equipped laboratories and technical facilities covering 30,000 m2 of useable space have been set up for this purpose at the sites in Dresden and Hermsdorf. Based on comprehensive materials expertise in advanced ceramic materials, the institute's development work covers the entire value creation chain, all the way to prototype production. Fraunhofer IKTS forms a triad of materials, technology and systems expertise, which is enhanced by the highest level of extensive materials diagnostics for materials beyond ceramics. Chemists, physicists, materials scientists and engineers work together on an interdisciplinary basis at IKTS. All tasks are supported by highly skilled technicians.

1. Carbon membrane on the inside of 19-channel tube substrates located in a membrane module of project partner DBI-GUT GmbH.
Image Courtesy: Fraunhofer IKTS © DBI-GUT GmbH



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Power Paste: Hydrogen-powered drives for e-scooters

Source : Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM

Pilot center planned for 2021
Fraunhofer IFAM is currently building a production plant for POWERPASTE at the Fraunhofer Project Center for Energy Storage and Systems ZESS. Scheduled to go into operation in 2021, this new facility will be able to produce up to four tons of POWERPASTE a year – not only for e-scooters.

Hydrogen is regarded by many as the future of propulsion technology. The first hydrogen-powered cars are already in action on German roads. In the case of e-scooters, however, installation of a high-pressure tank to store the hydrogen is impractical. An alternative here is POWERPASTE. This provides a safe way of storing hydrogen in a chemical form that is easy to transport and replenish without the need for an expensive network of filling stations. This new paste is based on magnesium hydride and was developed by a research team at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Dresden.

Gasoline and diesel engines, which are powered by fossil fuels, will soon be side-lined by climate change. Instead, new propulsion systems will be required. One fuel with a big potential is hydrogen. Hydrogen vehicles are equipped with a reinforced tank that is fueled at a pressure of 700 bar. This tank feeds a fuel cell, which converts the hydrogen into electricity. This in turn drives an electric motor to propel the vehicle. In the case of passenger cars, this technology is well advanced, with several hundred hydrogen-powered automobiles already in operation on German roads. At the same time, the network of hydrogen stations in Germany is estimated to grow from 100 to 400 over the next three years. Yet hydrogen is not currently an option for small vehicles such as electric scooters and motorcycles, since the pressure surge during refilling would be too great. Does this effectively shut out such vehicles from hydrogen technology?

POWERPASTE: the hydrogen technology for small vehicles

Not at all! Researchers from the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Dresden have now come up with a hydrogen-based fuel that is ideal for small vehicles: POWERPASTE, which is based on solid magnesium hydride. "POWERPASTE stores hydrogen in a chemical form at room temperature and atmospheric pressure to be then released on demand," explains Dr. Marcus Vogt, research associate at Fraunhofer IFAM. Given that POWERPASTE only begins to decompose at temperatures of around 250 °C, it remains safe even when an e-scooter stands in the baking sun for hours. Moreover, refuelling is extremely simple. Instead of heading to the filling station, riders merely have to replace an empty cartridge with a new one and then refill a tank with mains water. This can be done at home or underway.

The starting material of POWERPASTE is magnesium, one of the most abundant elements and, therefore, an easily available raw material. Magnesium powder is combined with hydrogen to form magnesium hydride in a process conducted at 350 °C and five to six times

Image Courtesy: Fraunhofer IFAM

atmospheric pressure. An ester and a metal salt are then added in order to form the finished product. On board the vehicle, the POWERPASTE is released from a cartridge by means of a plunger. When water is added from an on board tank, the ensuing reaction generates hydrogen gas in a quantity dynamically adjusted to the actual requirements of the fuel cell. In fact, only half of the hydrogen originates from the POWERPASTE; the rest comes from the added water. "POWERPASTE thus has a huge energy storage density," says Vogt. "It is substantially higher than that of a 700 bar high-pressure tank. And compared to batteries, it has ten times the energy storage density." This means that POWERPASTE offers a range that is comparable to or even greater than – gasoline. It also provides a higher range than compressed hydrogen at a pressure of 700 bar.

Suitable for e-scooters and other applications as well

With its huge energy storage density, POWERPASTE is also an interesting option for cars, delivery vehicles and range extenders in battery-powered electric vehicles. Similarly, it could also significantly extend the flight time of large drones, which would thereby be able to fly for several hours rather than a mere 20 minutes. This would be especially useful for survey work, such as the inspection of forestry or power lines. In another kind of application, campers might also use POWERPASTE in a fuel cell to generate electricity to power a coffeemaker or toaster.

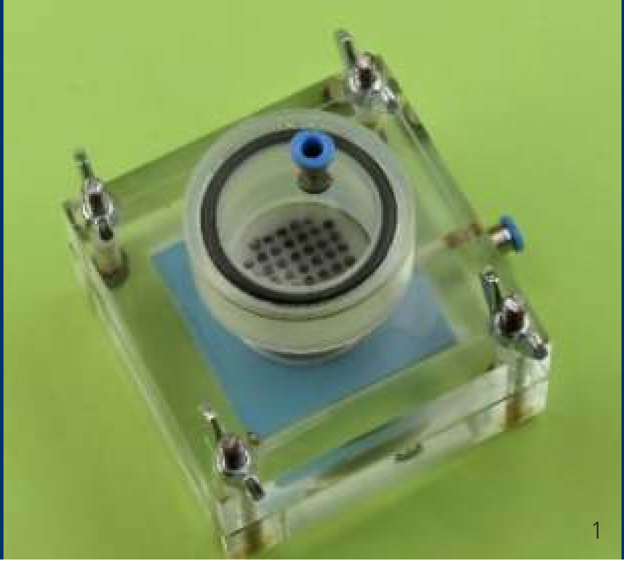
POWERPASTE helps overcome lack of infrastructure

In addition to providing a high operating range, POWERPASTE has another point in its favour. Unlike gaseous hydrogen, it does not require a costly infrastructure. This makes it ideal for areas lacking such an infrastructure. In places where there are no hydrogen stations, regular filling stations could instead sell POWERPASTE in cartridges or canisters. The paste is fluid and pump able. Therefore, it can be supplied by a standard filling line, using relatively inexpensive equipment. Initially, filling stations could supply smaller quantities of POWERPASTE – from a metal drum, for example – and then expand in line with demand. This would require capital expenditure of several tens of thousands of euros. By way of comparison, a filling station to pump hydrogen at high pressure currently costs between one and two million euros for each fuel pump. POWERPASTE is also cheap to transport, since no costly high-pressure tanks are involved nor the use of extremely cold liquid hydrogen.

About Fraunhofer IFAM:

The Fraunhofer IFAM is one of the most important research institutions in Europe for adhesive bonding technology, surfaces, shaping and functional materials. At Its institute's five locations – Bremen, Dresden, Stade, Wolfsburg and Braunschweig as well as at the Test Center for Maritime Technologies on Helgoland – Fraunhofer IFAM puts its central principles into practice: scientific excellence, a focus on the application of technology, measurable utility for customers and ensuring the highest quality. Fraunhofer IFAM's round about 700 employees, working in 20 departments and numerous working groups combine their broad technological and scientific knowledge and expertise into core competencies: Metallic Materials; Polymeric Materials; Surface Technology; Adhesive Bonding Technology; Shaping and Functionalization; Electro-mobility; and Automation and Digitalization.

2. TRL5 demonstrator of a power generator with inserted POWERPASTE cartridge and 100 W PEM fuel cell
Image Courtesy: © Fraunhofer IFAM



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PEM-Electrolyzer

Source : Fraunhofer Institute for Ceramic Technologies and Systems IKTS

The Fraunhofer IKTS develops miniaturized and robust water electrolysers for the local production of combustion gases (H2, O2). This enables the decentralized applications of relevant systems (e. g. flame ionization detector) as field devices, for instance. The investigated electrolyser uses a polymer-electrolyte-membrane (PEM) to dissociate the water molecule. The PEM-component is fixed in a ceramic package based on the ceramic multilayer technology (here: LTCC), consisting of a gas distribution device, terminations and seal. In addition, this approach provides the integration of sensory elements (e.g. temperature, pressure) for a more precisely control of the electrolyzing process.

Technical characteristics

- Producible gas flow H2 (scaled to active area) @ 2.2 V: 5.25 ml/(min*cm²)
- Supply voltage 1.6 V to 2.2 V
- Realized pressure: 5 bar

Service offered

- Customized development and design based on phenomenological models
- Integration of sensory elements (e. g. temperature, pressure) for system control
- Mass production by technology transfer to industrial partners

Micro fuel cell

Fuel cells convert chemical energy directly into electrical energy and thereby have a high electrical efficiency. In the department "Microsystems, LTCC and HTCC" LTCC-based low-temperature fuel cells with polymer membrane (Nafion) are developed. Electrochemically active elements (MEA, GDL), the hydrogen tank and the electronics of the battery management system are fully integrated. Thereby hydrogen is used as fuel gas. A serial circuit of the electrochemically active regions (usually up to 6 cells) increases the cell voltage of the fuel cell system. For status monitoring inside the fuel cell pressure and temperature sensors are integrated. Miniaturized valves are used to open or close the hydrogen tanks and for flushing the channel structures, the fuel gas distribution.

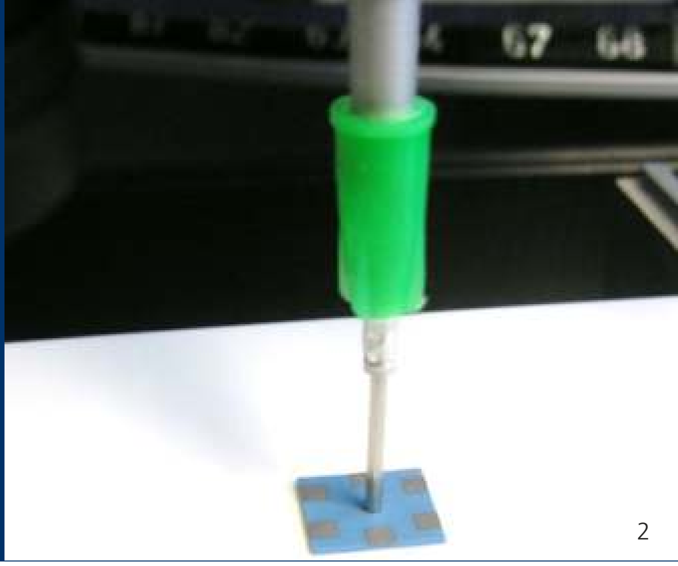
Technical characteristics:

- Active membrane area of (1 - 33) cm²,
- Power range from 150 mW to 5 W,
- Energy content 30 W (operating time 10h) and
- Fuel tank capacity 20Nl H2.

Services offered:

Development of PEMFC solutions & adaptation for application as mobile energy storage (galvanic cell and electrolysis cell)

Assembled PEM- electrolyser in operation setup
Image Courtesy: Fraunhofer IKTS



Micro battery

An LTCC micro battery consists of two bonded LTCC half-shells with cavities for electrodes and electrolyte. For a successful battery production following requirements for the LTCC half-shells are necessary:

- Low thickness (<0.5 mm),
- Low content of precious metals,
- Sufficient flatness,
- Manufacturability considering the allowable heat treatment of individual components and
- SMD integration.

In the illustrated version, the lateral dimension of the battery is (10 x 10) mm² and the depth of the cavity is 100 microns. The electrode covers an area of (6 x 6) mm². The studies on the stability of different LTCC substrates in fluoride-containing electrolyte show that LTCC is very suitable for the production of micro-batteries.

Technical characteristics:

- Total size (10 x 10) mm²
- Complete thickness: (0.7 - 2) mm
- Active area (cavity): (6 x 6) mm²
- Cavity depth 50-100 microns
- Cell voltage of 3.7 V (Li-Ion)
- Capacity: 1.5 - 2.2 mAh/cm
- Bonding of the half shells by gluing or soldering processes (metal, solder, solder glasses)

Services offered:

- Development of ceramic carriers for micro batteries
- Adaptation of housing solutions for applications in the fields of IC or MEMS packaging and energy harvesting

2. Electrolyte filled and joined LTCC battery
Image Courtesy: Fraunhofer IKTS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Ceramic Energy Converters

Source : Fraunhofer Institute for Ceramic Technologies and Systems IKTS

High-temperature fuel cells (SOFC) and high-temperature electrolysis cells (SOEC) have had a long history at Fraunhofer IKTS. The Ceramic Energy Converters workgroup did a research on SOFCs (solid oxide fuel cells) as early as the 1990s and in doing so gathered an extensive knowledge on the design and production of planar fuel cell stacks. The range of competences covers glass solder development, tape technology, as well as the design and processing of interconnectors, cell development and contacting on the gas and airsides, joining techniques, simulation and the initializing of SOFC stacks.

SOFC stack development

High-temperature fuel cell stacks are a core component in any SOFC system. Their performance and reliability, as well as the reproducible manufacturing at moderate cost, are prerequisites for fuel cell systems finding wider use on the market.

Researchers of Fraunhofer IKTS support users in the development of stack designs that are tailored to the client's requirements. This includes the construction of prototypes as well as the testing of system performance using standardized and adapted characterization techniques. For instance, Fraunhofer IKTS along with its partners develops fuel cell stacks for use in decentralized energy supply systems – from micro-CHP units to systems with more than 20 kW power. Furthermore, the research institution configures for its clients automatable manufacturing processes for the cost-efficient manufacturing of fuel cells.

High-temperature electrolysis

In the early 2000s, the researchers transferred their experience and the trends from fuel cell research to the field of high-temperature electrolysis (SOEC), which represents the reverse function of the SOFC operation. In the electrolytic mode, a voltage is applied and water vapour, carbon dioxide or a mixture of both gases (co-electrolysis) are reduced. The excess electric power results in a fuel gas, which can be stored and converted back into electricity.

However, the fuel gas can also be used as syngas in the Fischer-Tropsch synthesis, for the sustainable production of chemical products. A few research projects at Fraunhofer IKTS are currently trying to refine this process.

rSOC: Generator of electricity and energy storage in one single system

The latest developments aim at integrating the generation of electricity and its storage into one single system. To achieve this, the Ceramic Energy Converters group has developed what is called a 'reversible solid oxide cells', or rSOCs. These reversible high-temperature solid oxide cells combine the advantages of the fuel cell with those of the electrolytic cell. This creates an efficient, reversible energy conversion system, which generates electricity, stores excess electric energy and feeds it back into the cycle if needed – or produces chemical substances in a sustainable way in an additional recycling route.

1. 30-level MK352 stack made of CFY interconnectors: The heart of fuel cell, electrolysis and alternating power conversion systems.
Image Courtesy: © Fraunhofer IKTS

2. Assembly of a CFY stack.
Image Courtesy: © Fraunhofer IKTS

Quality assurance for SOFC, SOEC and rSOC

For rSOCs as well as for fuel cells and electrolytic cells, activities focus on keeping costs and degradation rates down. This includes individual components in the same way as the stacks and complex energy systems. Fraunhofer IKTS is a part of the global network of partners, and is setting standards for the testing of components, stacks and stack modules with regard to long-term testing, cyclization and analyses of accelerated aging processes.

Our current research includes process development for the commercial production of SOC cells and stacks

For more than 20 years, Fraunhofer IKTS has conducted intensive research on high-temperature fuel cells (SOFC) with electroyte-supported cells, with the focus in recent years placed increasingly on their use in high-temperature electrolyzers (SOEC). For this reason, IKTS has developed bidirectional SOC cells and stacks. They are key components for the conversion of excess power to synthetic gas, liquid fuels and their efficient conversion back to electric power. SOC stacks based on a chromium-based alloy of the MK35x design have now reached a sufficient level of technology to be transferred into commercial production. In collaboration with mPower GmbH, a pilot production scheme with a capacity of 1 MW/year and an extended capability of 10 MW/year was conceived based on the well-established prototype production at IKTS. For the steps of lab production that determine the production rate, such as coating, stack assembly and joining, specific automated solutions were developed. As a result, a process chain suitable for series production was designed and configured, which achieves a maximized output quota with minimal equipment and manpower requirements. Continuous screen printing and drying technology for cell production, including the non-destructive examination of the ceramic electrolyte, resulted in higher output rates. The semi-automated glass application machine (SANGAM) developed at IKTS reduces the cycle time for assembling single components by 70 % and enables an automated stacking procedure. The technical breakthrough came thanks to a change of technology at the glass sheet application. The glass is sintered and molten in the joining process and seals the fuel gas from the air and the surrounding atmosphere. As this process requires a lot of energy, heat treatment was reduced significantly and the reduction was experimentally validated. Adapted joining machines were designed which need 90 % less energy than state-of-the-art devices. The core components and improved processes thus developed enable the production of 1 MW/year (1000 stacks including cell production) on less than 500 m2 production space.

Services offered for fuel cells and electrolysis systems

- Testing of stack components for fuel cells and electrolysis cells (SOFC/SOEC/rSOC) under real operating conditions
- Testing of SOFC/SOFC/rSOC stacks of different sizes
- Stack and stack module development for use in SOFC/SOEC/rSOC systems, through to prototype manufacturing
- Analysis of degradation processes in SOFC/SOEC/rSOC stacks and clarification of the degradation mechanisms
- Marketing of SOFC/SOEC/rSOC stacks and fuel cells/electrolysis modules for various applications

3. Glass application and stacking machine for SOC stacks.
Image Courtesy: © Fraunhofer IKTS

An interview with

Dr. Ashish Lele

Director, Council of Scientific & Industrial Research (CSIR)
National Chemical Laboratory (NCL)

1. Why is hydrogen considered a sustainable fuel? What is the role of Green hydrogen in energy transition?

When hydrogen is employed as a fuel, instead of carbon-based fuel (such as gasoline, diesel), it gives energy and water as the only by-product. Further, 1 kg of hydrogen easily provides three times larger energy than any carbon-based fuel. When carbon-based fuel is employed as a fuel, there is emission of carbon dioxide, which is a primary pollutant of atmosphere and the major reason for climate change. Water which is the primary source of hydrogen, when split leads to hydrogen. However, if the energy employed for this water splitting process comes from renewable resources, such as solar energy, wind energy, the hydrogen produced is termed as green hydrogen, since carbon is not involved in the entire process. As we are aware, solar/wind energy is abundant and employing them makes hydrogen as a sustainable and/or green fuel.

2. What is the potential of commercial development of Hydrogen Tech in the context of Carbon Neutrality in India?

India being the top democracy of the world with a population of 1.36 billion, the power required for a variety of application needs to be fulfilled. More than 80% of energy/fuel requirement of India comes from other countries. Hence it is important for India to invest in green hydrogen (and/or carbon neutral), and to become energy independent from other countries. Hence the potential of commercial development of hydrogen technologies is very high in the context of carbon-neutrality, at least in near and medium terms. The biggest oil and power companies of India have already announced hydrogen production and pledged to invest a combined sum of US$ 30 billion, which is expected to bring down the price of green hydrogen to a level of 1 $/kg by 2030. Lately oil-to-fuel scenario is gradually changing to oil-to-chemical and the space created is an opportunity to be filled by (any coloured) hydrogen in the near-term.

3. How do you see the Potential Role of Hydrogen in India? What are the Challenges and Solutions for Energy Transition and Hydrogen Economic Development in India?

India is moving again after the Covid-break, in the fast lane of development, and that requires plenty of energy. Hence the role of hydrogen in India is certainly very bright. However, there are challenges, such as creation of specific infrastructure required for green hydrogen generation, storage and transport to the dispensation locations. More than 80% of alkaline electrolyzer components could be made in India and this technology is expected to lead from the front. India is also blessed with more than 80 % sunny days, and hence, solar energy harvesting is ramping up very fast. Electrons available should be converted into hydrogen. Government is likely to announce the legislations very soon to promote the employment of hydrogen in various applications, and this is expected to promote the energy transition from the current carbon-based energy to hydrogen-based solutions. Power/energy industrial sectors are expected to play a prime role in the hydrogen economy.

4. What are the steps being taken by the Government for use of Hydrogen in an Energy / Automotive sector in India?

Shri Narendra Modi, Prime Minister of India has announced on the Independence Day (Aug. 15, 2021) that Green hydrogen will be India's biggest goal for providing a quantum jump to address the climate change. Followed by this announcement, ministry of new and renewable energy (MNRE, Central ministry to oversee the implementation of green hydrogen as a source of energy) has made several announcements, such as national green hydrogen mission, hydrogen production from electrolysis and using the same for various applications, such as energy and automotive sector, heavy industries in a phased manner. Scientific and administrative meetings are conducted to make well-defined green hydrogen road-maps, policies etc. DST, CSIR also has invited major hydrogen-based research projects, which is expected to help the industrial sector to develop independent and innovative technologies.

5. Will hydrogen and electro mobility develop in the future in the Energy / Automotive industry?

India is a vast country with varied requirements in energy as well as automotive sectors. While electrons, harvested from solar energy, can be transported easily with the existing electrical transmission infrastructure, hydrogen mobility and hydrogen for mobility needs to be developed. Indeed, hydrogen for mobility is the best way to tackle the CO2 emission from all automotive sources and it is inevitable that it will be developed. Especially the long distance buses/trucks would be the first to attempt shifting to hydrogen fuel, as it would reduce the CO2 emission significantly. This is expected to propel PEMFC technology. In addition, there are industries and start-ups are already looking into such opportunities. Battery technology is also catching up fast and electro mobility is a possible potential industry to grow. However, lithium availability might become a key issue here, as Li-batteries are invariably used in electro mobility.

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Recent Research News @ Fraunhofer

Screen Printing to Produce Fuel Cell Electrodes
Annual Report/2021-2022

Within the "DEKADE" project that is funded by the German Federal Ministry for Education and Research (BMBF), Fraunhofer ISE has developed flatbed screen printing as a manufacturing process for fuel cell electrodes, which can be scaled up to industrial dimensions. To this purpose, we combined our competence in production and fuel cell technologies.

Standardized Measurements in PEM Water Electrolysis
Annual Report/2021-2022

The German National Hydrogen Strategy has focused public attention on the production of green hydrogen as an important driver for the energy transformation. Producing green hydrogen by PEM electrolysis with the help of electricity from renewable sources is a particularly promising approach. To achieve the targeted power densities, it is essential to further develop both the technology and the applied materials. Fraunhofer ISE is working within the framework of the International Energy Agency (IEA) to develop standardized measurement equipment and harmonized test protocols.

High-Resolution Measurement Technology Offers New Insights into Methanol Synthesis
Annual Report/2021-2022

With more than 100 million tonnes being produced annually, methanol is one of the chemicals that are produced in the largest quantities globally. By contrast, a methanol synthesis based on electrolytic hydrogen from sustainable energy and CO2 makes a technical carbon cycle and coupling of the energy, chemical and transport sectors feasible. Fraunhofer ISE is investigating this synthesis in a miniplant, which was planned, built and taken into operation in 2019 within the "Power-to-Methanol" project funded by the German Federal Ministry for Economic Affairs and Energy (BMWi)

Ammonia as a Platform Molecule for Sector Coupling
Annual Report/2021-2022

A recent study by Fraunhofer ISE on Power-to-X (PtX) value chains reveals that ammonia has various advantages when compared to other PtX products. A modern ammonia synthesis offers new opportunities concerning the total process efficiency, manufacturing costs and sustainability. Fraunhofer ISE is exploring this potential together with their Japanese partner, the National Institute of Advanced Industrial Science and Technology (AIST). Fraunhofer ISE is focusing on the application of second generation catalysts in combination with innovative process intensification technologies. Fraunhofer ISE's goal is a customized ammonia synthesis with higher yields per time and volume, taking dynamic operation into account.

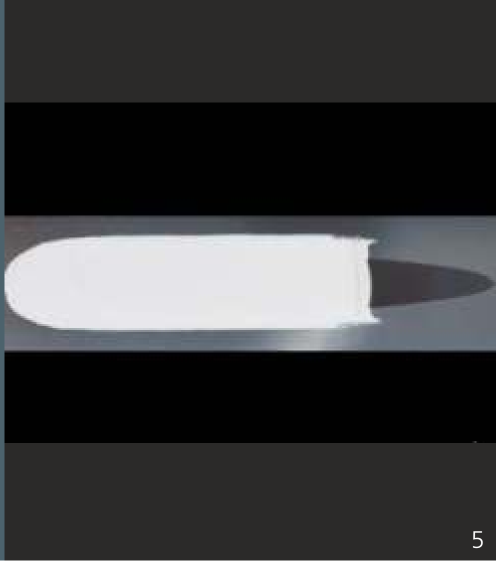
Printed Lithium Solid-State Batteries with Sulfide-Based Ion Conductors
Annual Report/2021-2022

In the "Printsolid" project, funded by the Vector Stiftung, Fraunhofer ISE is developing printing processes for such solid-state batteries with sulfide-based solid electrolytes. It has succeeded in producing a battery cell in which both the cathode and the ion-conducting separator layer between the cathode and the anode can be printed. The battery cell reaches more than 1000 charging / discharging cycles with relatively high charging (1C, corresponding to one charge per hour) and discharging (C/ 2, corresponding to one discharge in two hours) currents for a solid-state battery. After 1000 cycles, 80% of the original discharging capacity was still available. This type of solid-state battery is of great interest for consumer electronics but above all for electromobility.

1. Fuel cell electrodes on transfer films during the drying process. In the next step, these are laminated onto a membrane and then form the heart of the fuel cell.

2. Reference test cell with device for controlled application of clamping pressure. In the foreground are two half-cells with a parallel flow field.

3. Miniplant at Fraunhofer ISE.



2nd - Life Car Batteries in Stationary Applications
Annual Report/2021-2022

In the "EMILAS" project that is supported by the German Federal Ministry for Economic Affairs and Energy (BMWi), batteries are tested for their 2nd-life application as stationary buffer storage units in apartment blocks. In addition, with the cooling deactivated, Fraunhofer ISE investigated the suitability of the batteries for stationary application and determined the thermal switch-off limit of the battery management for high discharging currents. For the initial control, the batteries were subjected to capacity tests and pulsed tests in a test stand specifically programmed for this purpose, in order to determine their state of health. All investigated batteries were found to be suitable for further use. We are currently developing a thirty-minute quick test based on the processes for initial control and quality checks.

"Haid-Power": Active Grid Relief by Commercial PV-Battery Storage
Annual Report/2021-2022

In addition to the expansion of electricity generated from fluctuating renewable energy sources, the ongoing electrification of the transport sector is accompanied by an appreciable transformation of the electricity sector and presents another major challenge to the German electricity grid. Far-reaching changes concerning the grid load can be expected particularly in the distribution grids as sector integration proceeds. In the "Haid-Power" project, which is funded by the State Ministry for Economics, Labor and Housing in Baden-Württemberg, Fraunhofer ISE is preparing solutions for these problems and testing them in practice.

Quality Control of Battery Cells in the Production Process
Annual Report/2021-2022

Ensuring reliable production processes for high-quality battery cells is a complex task in which several factors must be taken into account. The end-of-line quality control of battery cells is a key instrument to identify optimization potentials early and reduce production costs. Non-destructive in-line quality control of the battery cells is thus the approach we are pursuing in the "OrtOptZelle" project that is funded by the German Federal Ministry for Education and Research (BMBF).

Fuel cells: Production chains ready for the market enable the economic breakthrough
Press release / 24 August 2021

Researchers at the Fraunhofer Institute for Machine Tools and Forming Technology IWU, for Material and Beam Technology IWS, for Ceramic Technologies and Systems IKTS and the Fraunhofer Institute for Production Technology IPT are working on the cost-effective, demand-oriented and scalable series production of fuel cells. The roll embossing developed at Fraunhofer IWU offers unique possibilities for continuously inserting the characteristic flow field of such a plate by means of a rotating rolling motion. Fraunhofer IKTS is also researching another coating process for mass production.

Lightweight battery pack advances e-mobility: Low weight and efficiently produced
Press release / 24 August 2021

Researchers at the Fraunhofer Institute for Durability and System Reliability LBF have developed a lightweight battery pack that exclusively uses fiber-plastic composites. As a result, the weight could be reduced by 40 percent compared to aluminium housings. This design not only reduces the moving mass of an electric vehicle, but also increases its range and dynamics thanks to additional integrated functions. Because the battery pack is manufactured in a specially developed highly efficient process and has a specific structure, it can be produced very cheaply.

4. 3D CAD drawing of the KISS facility for powder and particle kinetic investigations, where advanced catalysts for ammonia synthesis are investigated.

5. Aluminium current collector foil with a printed cathode (right, black) and a separator layer (left, white) printed on top of it.

6. Characterization of a used car battery in the Fraunhofer ISE laboratory.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Recent Activities

The year 2020 struck life at its very roots with COVID-19, a global pandemic that changed everything we know about work, life and family. With the pandemic still at its heels, the year 2021 saw a slight improvement as offices all over slowly re-opened. Our team here at the India office had all the necessary infrastructure and tried our best to keep in touch with the clients, and also create instruments that could reach out to the clients much faster and in a more structured manner. Here is a compilation of all the activities from 2019 to 2021.

5th Indo German Intergovernmental Consultations
1st November 2019

Exchange of MoU between Fraunhofer and Council of Scientific and Industrial Research (CSIR), Govt. of India to strengthen scientific and applied research innovation ecosystem in India in the areas of Battery Technologies, Water Management, Sustainable Building Technologies and Advanced Production Technologies during 5th Indo-German Intergovernmental Consultations in New Delhi in presence of Shri. Narendra Modi, Hon'ble Prime Minister of India and H.E. Dr. Angela Merkel, Chancellor of the Federal Republic of Germany.

8th Indo German Energy Forum-Women Empowering the energy transition
1st November 2019

The 8th Indo German Energy Forum - Women Empowering the energy transition was represented by Ms Anandi Iyer, Director, Fraunhofer office India. During this event she also met with Mrs. Julia Kloeckner, Federal Minister for Food, Agriculture and Consumer Protection, Govt. of Germany.

H.E. Dr. Angela Merkel, Chancellor of the Federal Republic of Germany visited the 63rd Annual General Meeting of the Indo-German Chamber of Commerce (IGCC)
2nd November 2019

Fraunhofer was the "Innovation Partner" to the 63rd Annual General Meeting of the IGCC. Fraunhofer Office India also held a booth, featuring and showcasing its competencies in Artificial Intelligence, Industry 4.0, Smart City and Renewable energy through poster presentation. Also, an introductory meeting with Mrs. Anja Karliczek, Federal Minister for Education and Research, Govt. of Germany was held.

A Session on "Education-Research-Skills for Economic Growth" held
15th November 2019

Ms. Anandi Iyer delivered a presentation on "Converting Research into Products" in the session on "Education-Research-Skills for Economic Growth" at EDU Summit - Reimagining the future of Higher Education organized by Confederation of Indian Industry (CII).

Germany's Energiewende visits India
18th November 2019

Germany's Energiewende visited Bangalore India. Ms. Anandi Iyer, Director, Fraunhofer Office India was the moderator of the panel discussion on 'Energiewende in India - Status quo and the future'.

High-level panel discussion on "Artificial Intelligence – Driver of Sustainability"
19th November 2019

A high-level panel discussion on "Artificial Intelligence – Driver of Sustainability" in Bangalore Technology Summit 2019 organized by Govt. of Karnataka. Ms. Anandi Iyer, Director, Fraunhofer Office India participated as a speaker.

1. Dr. Angela Merkel, Chancellor-Federal Republic of Germany with other dignitaries at the 63rd IGCC

2. Ms. Anandi Iyer delivering presentation at CII-EDU Summit

3. Ms. Anandi Iyer moderating the panel discussion on 'Energiewende in India - Status quo and the future'

"Futuras in Res 2019 What 's the IQ of AI?"
20th-22nd November 2019
Ms. Anandi Iyer represented Fraunhofer Office India in "Futuras in Res 2019 What 's the IQ of AI?" organized by Fraunhofer HQ in Berlin. She also coordinated the participation of Prof. Padmanabhan Anandan, CEO, Wadhwani AI, who was one of the speakers in the panel on "Empathy & Human-Machine-Interaction" in this conference.

Intersolar India 2019, Bangalore
28th November 2019
Mr. Sanmati Naik, Fraunhofer Office India participated in the panel discussion on "Potential of AgroPV in India - Opportunities for Indian Industry", organized by National Solar Energy Federation of India (NSEFI) and Indo-German Energy Forum (IGEF) during Intersolar 2019 in Bangalore.

Conference on "Culture Fit" - German and Indian SMEs
29th November 2019
Ms. Anandi Iyer, Director, Fraunhofer Office India delivered a presentation on "Examples of Best Practices of successful Indo-German cooperation in India" in the conference on "Culture Fit - German and Indian SMEs", organized by Maratha Chamber of Commerce, Industries & Agriculture (MCCIA), Goethe Institute and Consulate General of Federal Republic of Germany in Mumbai.

On-site assessment of Kochi under the project "Kochi Smart City Innovation lab"
13th-22nd January 2020
A delegation of experts from Fraunhofer, Frankfurt School of Finance, University of Stuttgart and National Institute of Urban Affairs (NIUA) visited Kochi between 13th - 22nd Jan 2020 to conduct on-site assessment of the city under the cooperation between Fraunhofer and Cochin Smart Mission Ltd. (CSML) for the project "Kochi Smart City Innovation Lab". The on-site assessment concluded with a "Smart City Project Development Workshop" on Jan 22nd 2020, where the results of the assessment were presented and the measures that CSML should embrace against climate change were discussed.

Workshop on Mathematical Modelling of Complex Industrial Problems at Fraunhofer Office India
13th January 2020
Fraunhofer Office India coordinated a workshop on "Mathematical Modelling of Complex Industrial Problems and Development of Efficient Algorithms (Simulation)" for Dr. Jörg Kuhnert from Fraunhofer ITWM on Jan 13th 2020 with senior representatives of Indian automotive and allied industries like Sundaram Clayton, Continental, Wipro-GE Healthcare Systems to name a few.

Indian Metal Cutting Machine Tool Exhibition (IMTEX) 2020
23rd - 28th January 2020
Fraunhofer Office India had held a booth in IMTEX 2020 and showcased the capabilities of Fraunhofer IWU in lightweight automobile components, forming technology, forging technology and additive manufacturing. Dr. Andreas Sterzing, Division Director "Bulk Metal Forming", Fraunhofer IWU was invited as a guest speaker by IMTMA at International Seminar on Forming Technology during IMTEX 2020. He delivered a presentation on "Advancement in Forming Technology and Lightweight Approach".

Large Scale Industry 4.0 Summit
4th February 2020
Maratha Chamber of Commerce, Industries and Agriculture (MCCIA) had organized a "Large

4. Prof. Padmanabhan Anandan speaking in Futuras in Res 2019

5. Mr. Sanmati Naik in Intersolar 2019

6. Dr. Andreas Sterzing delivering a presentation in International Seminar on Forming Technology during IMTEX 2020

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Scale Industry 4.0 Summit" on Feb 4th 2020 in Pune. Ms. Anandi Iyer, Director, Fraunhofer Office India was invited to present Fraunhofer's profile in Industry 4.0 in the international session on "Scope for Collaborative Opportunities" in this summit. A High Level Delegation from Karlsruhe and Baden Württemburg in Germany led by Ms. Theresa Schopper, State Minister of the State Baden Württemburg also attended this summit.

Visit of Committee on Economic Affairs & Energy, German Parliament to Bangalore 24th February 2020

The committee on Economic Affairs & Energy from German Parliament led by Mr. Klaus Ernst, (DIE LINKE), MdB - a left-wing German politician visited Bangalore on Feb 24th 2020 to explore the opportunity to have an Interactive session over various important topics like Start-up concept in Bangalore, latest trends and technologies in the IT Industry, Indo-German Initiatives and co-operation. In this regard, Mr. Karl Ehlerding, Acting Consul General, German Consulate Bangalore organized an Interactive session and invited Ms. Anandi Iyer, Director, Fraunhofer Office India to present an overview on the Indo-German initiatives and potential collaboration in the field of Artificial Intelligence.

Indo-German Start-up Collaboration Roundtable 28th February 2020

Invest India - the National Investment Promotion and Facilitation Agency of Govt. of India and German Embassy in India organized an Indo-German Start-up Collaboration Roundtable on Feb 28th 2020 in New Delhi. The roundtable was chaired by Mr. Christian Herte, Member of the German Parliament. Ms. Anandi Iyer, Director, Fraunhofer Office India was invited to deliver special remarks in the context of the Indo-German start-up ecosystem.

Visit of Dr. Markus Wolperdinger, Director, Fraunhofer IGB to India 2nd - 5th March 2020

Fraunhofer Office India coordinated the visit of Dr. Markus Wolperdinger, Director, Fraunhofer IGB to India on his interest to intensify the cooperation between Fraunhofer IGB and Indian companies. He visited Pune, Mumbai and New Delhi and was accompanied by Dr. Marius Mohr, Head of Innovation Field Water and Resource Recovery, Fraunhofer IGB. Fraunhofer Office India also coordinated a speaker slot for Dr. Wolperdinger in "International Business Summit" organized by Mahratta Chamber of Commerce, Industries and Agriculture (MCCIA) in Pune on March 3rd 2020. Meetings with important Indian companies and government institutes like Reliance Industries Ltd., Indian Tobacco Company (ITC), Hinduja Group, Environment Management Centre LLP, Council of Scientific and Industrial Research (CSIR), NITI Aayog, GIZ and German Embassy in India were also organized for Dr. Wolperdinger in Pune, Mumbai and New Delhi.

Online Event Series organized by Indo-German Business Forum 9th July 2020

Indo-German Business Forum organised an online event series on the topic "Innovation: A smart investment in challenging times" on July 9th 2020, and invited Ms. Anandi Iyer, Director, Fraunhofer Office India to be the guest speaker in this session. She spoke on the significance of collaborative technology partnerships between India and Germany to drive affordable innovation for the Indian geography.

Partnership Workshop between Fraunhofer and Wipro Ltd. 10th July 2020

Wipro Ltd., one of the largest IT Giants of India expressed its interest to enter into a long-term

7. Group Photograph with the committee members of Economic Affairs & Energy, German Parliament

8. Group Photograph of all the participants of the roundtable.

9. Dr. Markus Wolperdinger delivering presentation in International Business Summit


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strategic partnership with Fraunhofer in the areas of Smart Manufacturing / Industry 4.0, Renewable Energy, Mobility Concepts, Aviation Logistics, Smart Cities and Data Security. A workshop was organized with Wipro on July 10th 2020 at Fraunhofer Office India to discuss the modalities and to finalize the concept of cooperation.

Confederation of Indian Industry (CII) Innovation Summit 2020
16th September 2020

Fraunhofer Office India coordinated the participation of Prof. Dr. Boris Otto, Executive Director, Fraunhofer ISST as the keynote speaker in the 16th edition of CII Innovation Summit focussing on "Resilience & Resurgence: Innovating for Society 5.0". Prof. Otto delivered a presentation on "Data Sharing in Industrial Ecosystems" with a prime focus on technology as a driver for innovation and Industry.

German Day Digitales - Fraunhofer partners with Indo-German Chamber of Commerce (IGCC)
3rd -7th October 2020

The German Day Digitales was organized by IGCC to promote and strengthen economic and cultural ties between India and Germany. It was a virtual event inaugurated by H.E. Walter J. Lindner, Ambassador of the Federal Republic of Germany to India on Oct 3rd 2020. Fraunhofer Office India was one of the key partners to this event. Together with IGCC, Ms. Anandi Iyer, Director, Fraunhofer Office India also coordinated a high-level panel discussion on "Industry 4.0 – The fourth industrial revolution - Opportunities and Challenges" on Oct 5th 2020. Further, on Oct 7th 2020, German Centre for Research and Innovation (DWIH) had organized a special session and invited Ms. Anandi Iyer to be one of the panellists in this panel discussion on "Opportunities for Collaboration between Industry and Research Institutes in India".

Conference on AI & Digital Applications in Agriculture
8th October 2020

The German Agribusiness Alliance and Federation of Indian Chambers of Commerce and Industry (FICCI) organized a virtual international conference on "AI & Digital Applications in Agriculture" and invited Ms. Anandi Iyer to be a speaker in the panel discussion on "Future of Artificial Intelligence in Agriculture". The conference was organized in cooperation with German Federal Ministry of Food and Agriculture, Indian Ministry of Agriculture and Farmers Welfare and NITI Aayog, Govt. of India.

3rd Assembly of International Solar Alliance
14th October 2020

International Solar Alliance (ISA) organized its third assembly at the ministerial level in accordance with the ISA Framework Agreement and requested Ms. Anandi Iyer to participate as a special invitee in the ministerial plenary on Oct 14th 2020.

Kick-off Workshop of Project "AquaHub"
23rd November 2020

AquaHub focuses on setting up of Water Innovation Hubs and Smart Water Monitoring systems to promote Indo-German cooperation. The project is coordinated by Fraunhofer IGB. The first kick-off workshop of this project was conducted on Nov 23rd 2020, where the partners discussed the vision of the Water Innovation Hub for India, identified potential Indian partner for implementation, discussed the structure of the advisory board and also drafted the concept of Smart Water Quality Monitoring System. Ms. Anandi Iyer, Director,

10. L to R: Mr. Nisanth Ayyagari, Mr. Anshuman Mukherjee, Ms. Anandi Iyer, Mr. Aditya Fuke

11. L to R: Mr. Achim Burkart, Ms. Anandi Iyer, Mr. Karl, Philipp Ehlerding

12. AquaHub virtual kick-off meeting

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Fraunhofer Office India participated in this workshop and presented the present status of water sector in India and the impacts of COVID-19.

Fraunhofer as a Knowledge Partner to FICCI - DST Global Research & Development Summit 2020
25th -27th November 2020
The Global R&D Summit is an annual flagship event of FICCI (Federation of Indian Chambers of Commerce & Industry) organized in partnership with the DST (Department of Science & Technology, Govt. of India). Fraunhofer was invited to be the Knowledge Partner to this summit. Ms. Anandi Iyer was invited to be the chair of the session on "Innovation Clusters Session: The Savant Strategists", which focussed on discussion around innovation delivery model that works both locally and globally in the context of global pandemic. As a Knowledge Partner, Fraunhofer conducted a Knowledge Paper on "Changing Paradigms: Indian Innovation Ecosystem", authored by Ms. Anandi Iyer, Director, Fraunhofer Office India and co-authored by Prof. Rishikesha Krishna, Director, IIM-Bangalore. The paper was released in presence of Prof. Ashutosh Sharma, Secretary, DST and Mr. Dilip Chenoy, Secretary General, FICCI along with other eminent industry leaders during this summit.

Indo - German Research Day
3rd December 2020
Ms. Anandi Iyer was invited as a speaker in the panel discussion on "Research cooperation at research and technology organizations in the Indo-German context", at the Indo - German Research Day organized by German Centre for Research and Innovation (DWIH) New Delhi.

First Workshop with Wipro Ltd. on Industrial Automation and Robotics
21st January 2021
Fraunhofer Office India had coordinated a virtual workshop between Fraunhofer IPA and Wipro Robotics Practice (Wipro Ltd.) on Jan 21st 2021 to discuss and explore an opportunity for collaborative research in Industrial Automation and Robotics.

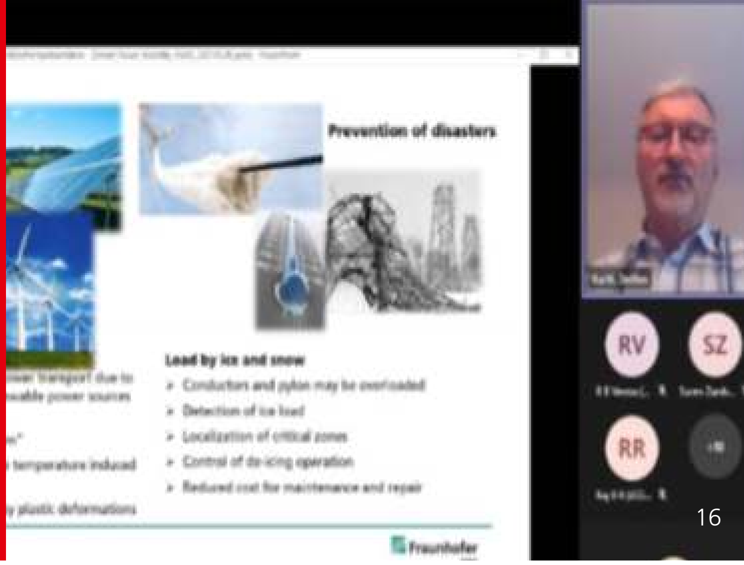
First virtual meeting of the Expert Group Digital Agriculture India-Germany
18th February 2021
The first virtual meeting of the Expert Group "Digital Agriculture India - Germany" was organized jointly by Fraunhofer, German Agribusiness Alliance and Federation of Indian Chamber of Commerce and Industries (FICCI), on Feb 18th 2021. The experts from both the sides discussed the topics of immediate importance that would uplift the Indian agriculture scenario by promoting applied research in development of innovative German technologies in the smart agricultural landscape.

28th CIRP Conference on Life Cycle Engineering
10th March 2021
28th CIRP Conference on Life Cycle Engineering was jointly organized by TU Braunschweig and BITS Pilani in virtual format from Mar 10th - 12th 2021.The objective of this conference was to engage and empower all participants to take the necessary actions required to develop technologies that foster sustainability worldwide and make "business as unusual" the new usual.

Indo-German Forum: Cities and Climate
16th-17th March 2021
A virtual Indo-German Forum: Cities and Climate was organized by DWIH New Delhi from

13. Dr Eva Ottendoerfer delivering Keynote during the Indo-German Forum: Cities and Climate.

14. Screenshot of the virtual workshop:
L to R: Dr. Marius Mohr, Dr. Rajan Chedambath, Ms. Anandi Iyer, Mr. Gerhard StryiHipp, Mr. M. Anilkumar, Ms. Sabine Gig



Mar 16th-17th 2021. Fraunhofer Office India coordinated the participation of Fraunhofer IAO and IMW in this forum.

Morgenstadt Global Smart City Initiative Stakeholder & Solution Workshop
21st April 2021

Morgenstadt Global Smart City Initiative Stakeholder & Solution Virtual Workshop for the city of Kochi was organized by Fraunhofer, University of Stuttgart, National Institute of Urban Affairs and Frankfurt School of Finance and Management, in support with Centre for Heritage, Environment and Development (C-HED) and Kochi Municipal Corporation (KMC). The workshop was outlined to present the City Profile of Kochi and to discuss the proposed project ideas in order to develop a pilot project in Elamakkara ward in Kochi.

IET India Digital Conversations - Confluence of Digital Transformation and Industry 4.0
21st May 2021

The Institution of Engineering and Technology (IET) - India had invited Ms. Anandi Iyer, Director, Fraunhofer Office India to moderate the leadership panel discussion on "Confluence of Digital Transformation and Industry 4.0". The panel discussed how Indian MSMEs can leverage emerging technologies like Data lakes, Platforms for supporting horizontal and vertical integration, Cloud Computing, AI/ML, IoT, AR/VR and cyber security etc. so that they become globally competitive and sustain over a long run.

Urban Thinkers Campus
4th June 2021

National Institute of Urban Affairs (NIUA), Govt. of India had partnered with Kerala Institute of Local Administration (KILA), Govt. of Kerala and organized the Urban Thinkers Campus on the theme "Climate Action" on June 4th and 5th 2021. Dr. Marius Mohr, Head of Innovation Field Water Technologies and Resource Recovery, Fraunhofer IGB was invited as a speaker to introduce the Kochi Smart City Innovation Lab, as a part of the Morgenstadt Global Smart Cities Initiative. Fraunhofer IGB is involved in the fields of water supply, wastewater treatment and flood protection. Dr. Mohr heads the City Lab in Kochi.

DWIH Science Circle Lecture
17th June 2021

DWIH had invited Prof. Dr. Martin Hofmann-Apitius, Head of Department "Bioinformatics", Fraunhofer SCAI to deliver a science circle lecture on the theme "Making a difference in AI" on June 17th in a virtual format. This session outlined how a strategic data collaboration between India and Germany could generate values in the fields of agriculture, technology and mobility beyond the health sector.

IET India Digital Conversations - Embracing Industrial Automation and Robotics
6th August 2021

The Institution of Engineering and Technology (IET) - India invited Ms. Anandi Iyer, Director, Fraunhofer Office India to moderate the leadership panel discussion on "Embracing Industrial Automation and Robotics", held on Aug 06th 2021. The panel discussed how Indian SMEs can leverage Industrial Automation and Industrial IoT and adopt globally accepted use cases to deliver values thereby maximizing RoIs and developing solutions locally at affordable costs in a phased-manner.

Webinar on "Building Sustainable Ecosystem for Electric Mobility - The Way Forward"
18th August 2021

The Associated Chambers of Commerce and Industry of India (ASSOCHAM) had organized a webinar on "Sustainable Ecosystem for Electric Mobility - The Way For ward" and had invited Ms. Anandi Iyer, Director, Fraunhofer Office India as one of the speakers in the panel.

15. Ms Anandi Iyer moderating the panel discussion during the leadership panel discussion on "Confluence of Digital Transformation and Industry 4.0"

16. Dr. Steffen Kurth delivering the presentation in the Tech Talk on "Technologies and Systems for Smart Power and Mobility"

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India launch of Global Innovation Index 2021 and Global Innovation Conclave
22 September 2021
The Confederation of Indian Industry (CII) in partnership with NITI Aayog, Govt. of India and the World Intellectual Property Organisation (WIPO) had organized the India Launch of the GII and the Global Innovation Conclave on Sept 22nd 2021. Ms. Anandi Iyer, Director, Fraunhofer Office India was invited as a speaker in the panel discussion on "G20 Economies - Hotspots of Global Innovation and Collaborations". The discussion was moderated by Dr. Gopichand Katragadda, Founder & CEO, Myelin Foundry. Dr. Renu Swarup, Secretary, Dept. of Biotechnology, Govt. of India delivered the special address in the session.

Indo-German Start-up Week 2021
22nd September 2021
The Indo-German Start-up Week 2021 was organized by the German Indian Startup Exchange Program (GINSEP) and from Sept 20th – 24th 2021. This one-week online summit brought together startup eco-systems of India and Germany to create impact for entrepreneurs, talent, investors and academia looking for support to internationalize. Ms. Anandi Iyer, Director, Fraunhofer Office India was invited as the Keynote speaker on the Science Day of this summit.

Launch of Fraunhofer Office India Webinar Series - Tech Talk
March 2021
Fraunhofer Office India has launched a new instrument in the year 2021 namely "Fraunhofer Tech Talk" to deepen the connect with the Indian companies. The team at Fraunhofer Office India has identified a list of interesting topics, which would be very well received by the Indian industries. The webinar series will help the Fraunhofer Institutes to concretize their approach in reaching out to the Indian industry even more by facilitating tech talks on these topics.

Webinars:
25th March 2021: Tech Talk on **"Fraunhofer Blockchain Lab"** by Prof. Dr. Wolfgang Prinz, Vice Chair and Deputy Director of Fraunhofer FIT.

15th April 2021: Tech Talk on **"Energy Harvesting technology to power wireless sensors in production environment"** by Dr. Peter Spies, Group Manager "Integrated Energy Supplies", Fraunhofer IIS

15th April 2021: Tech Talk on **"Industrial Polymers and Plastic"** by Dr. Robert Brüll and Dr. Ingo Alig, from Fraunhofer LBF

28th May 2021: Tech Talk on **"Technologies and Systems for Smart Power and Mobility"** by Dr. Steffen Kurth, Head of Department "Multi Device Integration" and Dr. Alexander Otto, Deputy Head of Department "Micro Materials Center" from Fraunhofer ENAS

28th June 2021: Tech Talk on **"Car Body – Forming (Sheet Metal), Manufacturing and Joining Technology"** by Mr. Frank Schieck, Divisional Director, Sheet Metal Forming and Dr. Reinhard Mauermann, Head of the Institute, Head of the Forming Technology Department from Fraunhofer IWU

30th June 2021: Tech Talk on **"Current Developments in Battery Technology - Highlights along the whole value chain"** by Dr. Matthias Vetter, Head of Department - Electrical Energy Storage from Fraunhofer ISE

29th July 2021: Tech Talk on **The "Why" behind trends in Robotics and Automation** by Dr. Werner Kraus, Head of Department "Robot and Assistive Systems" from Fraunhofer IPA

Fraunhofer India: Recent Media Coverage

Water Quality System

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Fraunhofer INT and Digital Science collaborate to bring Fraunhofer's Technology Foresight Tool KATI together with Dimensions data

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Digital Science; Fraunhofer Institute for Technological Trend Analysis (INT) →
Apr 12, 2021, 05:00 ET

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LONDON, April 12, 2021 /PRNewswire/ -- **The Fraunhofer Institute for Technological Trend Analysis (INT) and Digital Science are collaborating to enable the technology foresight tool KATI (Knowledge Analytics for Technology & Innovation) to be combined with Dimensions data covering 116 million publications and 1.4 billion citations. They are also working together to make KATI available for users and clients outside of the Fraunhofer Gesellschaft. The newly formed collaboration will be launched at the Hannover Messe 2021.**

Fraunhofer INT has developed and been using KATI for technology foresight and innovation management tasks carried out by researchers from Fraunhofer INT. The tool allows users to identify trends in large document sets and enables experts to quickly qualify and assess the data with the flexible analytical and visualization capabilities.

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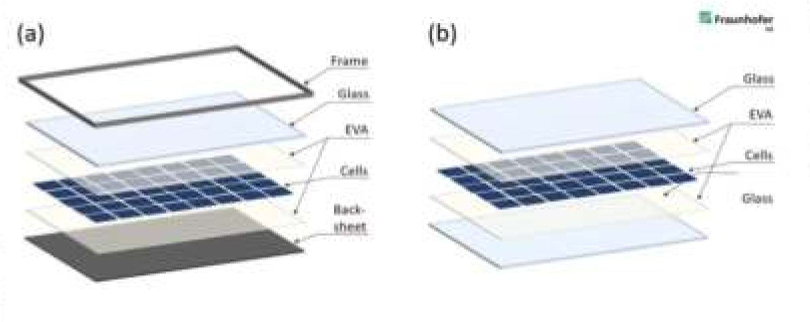
Modules Manufactured in Europe Emit 40% Less CO2 than the Chinese: Fraunhofer ISE

The CO2 emissions for glass-foil modules are 810 Kg/kWp in China and 480 Kg/kWp in the EU

SEP 28, 2021 / HARSH SHUKLA / SOLAR, TECHNOLOGY



Glass-glass PV modules (b) do not require an aluminum frame and therefore have a lower carbon footprint than PV modules with backsheet (a). Source: Fraunhofer ISE

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