green power electronics
innovation via new materials

GREEN POWER ELECTRONICS

Boosting efficiency in conversion, transmission and consumption of energy

EUROPEAN REGIONAL DEVELOPMENT FUND
EUROPEAN UNION

Interreg
Baltic Sea Region

WELCOME

The Baltic Sea Region (BSR) is well known for being forefront runner on the way to a sustainable green future. Energy efficient devices, smart energy system control and renewable energy sources are key words on that road. In this context, it is important to realise that more than 15.000 companies in the BSR are working with power electronics. To attach this industry to sustainable solutions using advanced power electronics has been the overarching goal of the Interreg 5B project Power Electronics for Green Energy Efficiency (Green PE). The project reached out to hundreds of companies and has raised the awareness of the innovation potential advanced power electronics has throughout the BSR.

In this brochure, some of the key findings of the project are exemplified, among others pilot projects within electromobility, smart houses and renewable energies. In these areas the project has revealed in detail the extent to which the progress of promotion and development differs in the various countries of the BSR.

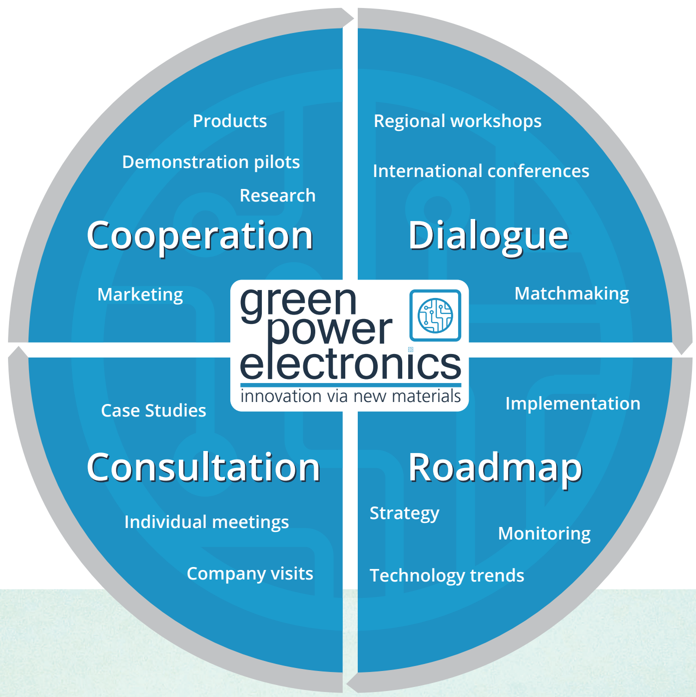
Having partners and network partners from both academia, industry and technology transfer organisations, the project has shown that a close intersectoral collaboration can create new ideas, products and solutions. The 'Centre for Industrial Electronics' that has been initiated in Sønderborg, Denmark, during the project lifetime as a joint endeavour of industry, academia, municipality and regional forces is an excellent example of such collaborative processes.

It is also a brilliant example for the fact that the project has generated a number of sustainable solutions that will further advanced power electronics in the BSR by university networks, industrial collaborations and product oriented joint developments.

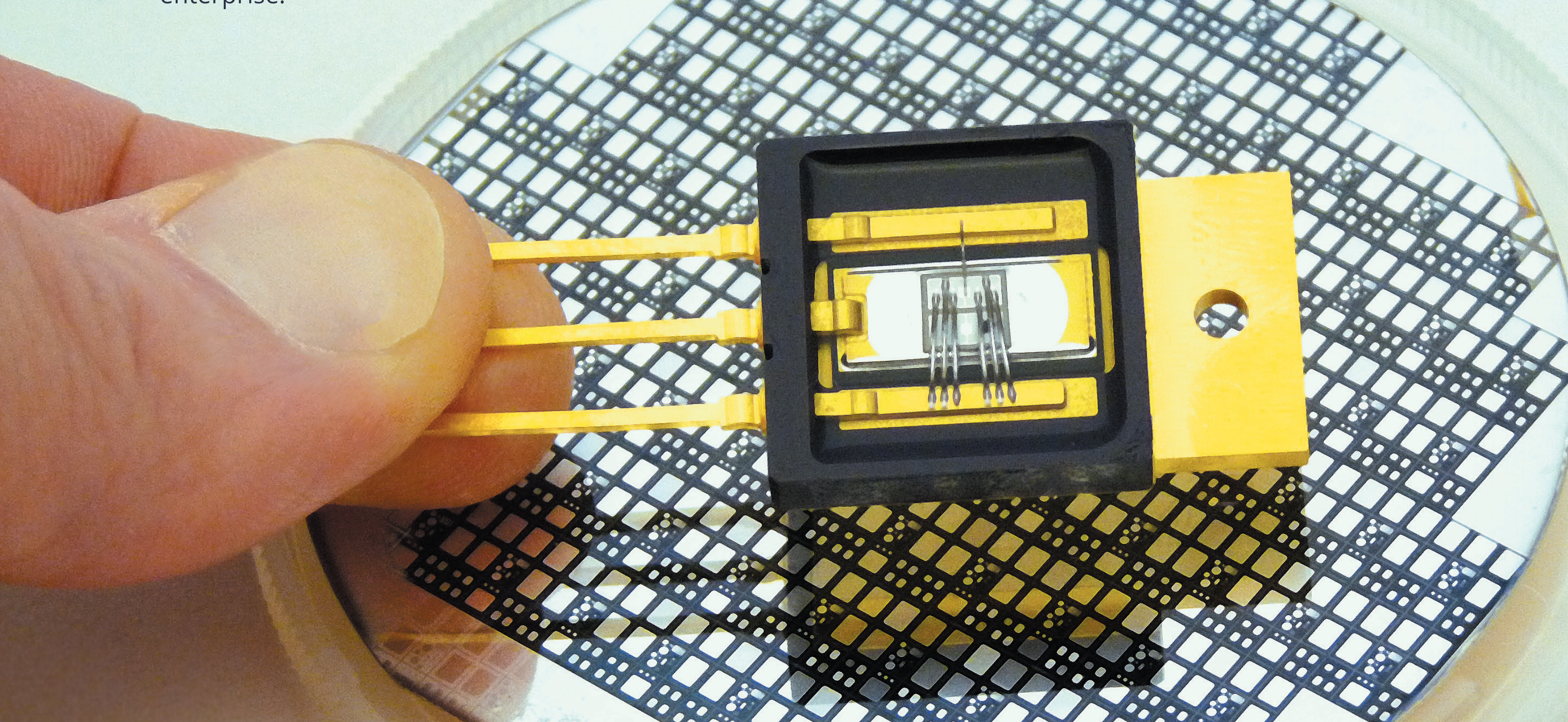
Prof. Dr Horst-Günter Rubahn
Director Mads Clausen Institute,
University of Southern Denmark,
lead partner

THERE IS A NEED FOR ADVANCED POWER ELECTRONICS

Power electronics (PE) is the art of managing and mastering electric apparatus: from smart energy use in high resolution flat screens to efficient energy conversion in huge wind turbine generators. PE that is based on next generation materials beyond Silicon such as wide bandgap semiconductors is called 'advanced power electronics' (APE). The novel technologies behind APE enable huge energy savings and allow to manage an increased power output of devices that grow smaller constantly. Furthermore, APE also prepares devices for smart digitalisation and is an essential part of efficient production, distribution and consumption of electricity in a renewable energy society.



A glance at new EU emission standards shows the strong societal pressure, urging to use energy more efficiently, to avoid CO_2 generating energy sources and to introduce smart, digital solutions into industrial production and municipal households. It is high time to shorten the way from best solutions in the laboratories to best practice in home and enterprise.



INSPIRING FUTURE POWER ELECTRONIC TALENTS

In the outskirts of Riga in Latvia, in the city of Ogre, the company Drive eO is committed to push the boundaries of high performance electrically powered race cars. Drive eO joined the Green PE project searching for further optimisation of their car through the implementation of APE in order to reduce weight, size and energy losses. After roughly three years of research, driven by the company and with participation of Green PE project partners University of Latvia, Warsaw University and the University of Southern Denmark both the overall power and the system voltage of the car could be significantly increased.

These results will also enter directly into Formula Student E activities at the University of Southern Denmark at its campus sites in Odense and Sønderborg.

Formula Student E is an international design competition where electric racing cars are developed and designed by engineering students.

That way the Green PE project provides the basis for further developments within the field of electromobility and inspires next generation of PE students to learn more about the benefits of advanced power electronics.

NETWORKING
TOWARDS GREEN GROWTH

Sweden
Teresita Qvarnström, RISE Research Institutes of Sweden, ICT Division, SME Development, Sweden:
"The smart houses concept demonstrated in Växjö with a DC grid and islandic capability is of strong interest for companies and funding agencies in Sweden. Stakeholders want to further develop the concept as a tool to increase the resilience of the energy infrastructure in case of power outages."

Denmark
Prof. Thomas Ebel, Head of Center for Industrial Electronics, Denmark:
"Devices become more energy efficient and systems break down less if electronics with new innovative materials is included. In fact, it is difficult to imagine clean and sustainable energy systems (from generation to use) without advanced power electronics."

Poland
Prof. Jan Szmidt, Rector of Warsaw University of Technology, Head of Microsystems and Microelectronic Materials Technology Department, Poland:
"The e-mobility sector is currently the most dynamically developed industry in Poland among the advanced power electronics sectors. Private companies have been delivering solutions supporting state-of-the-art public transport and power supply systems for industrial installations and the power sector."

PROJECT DATA

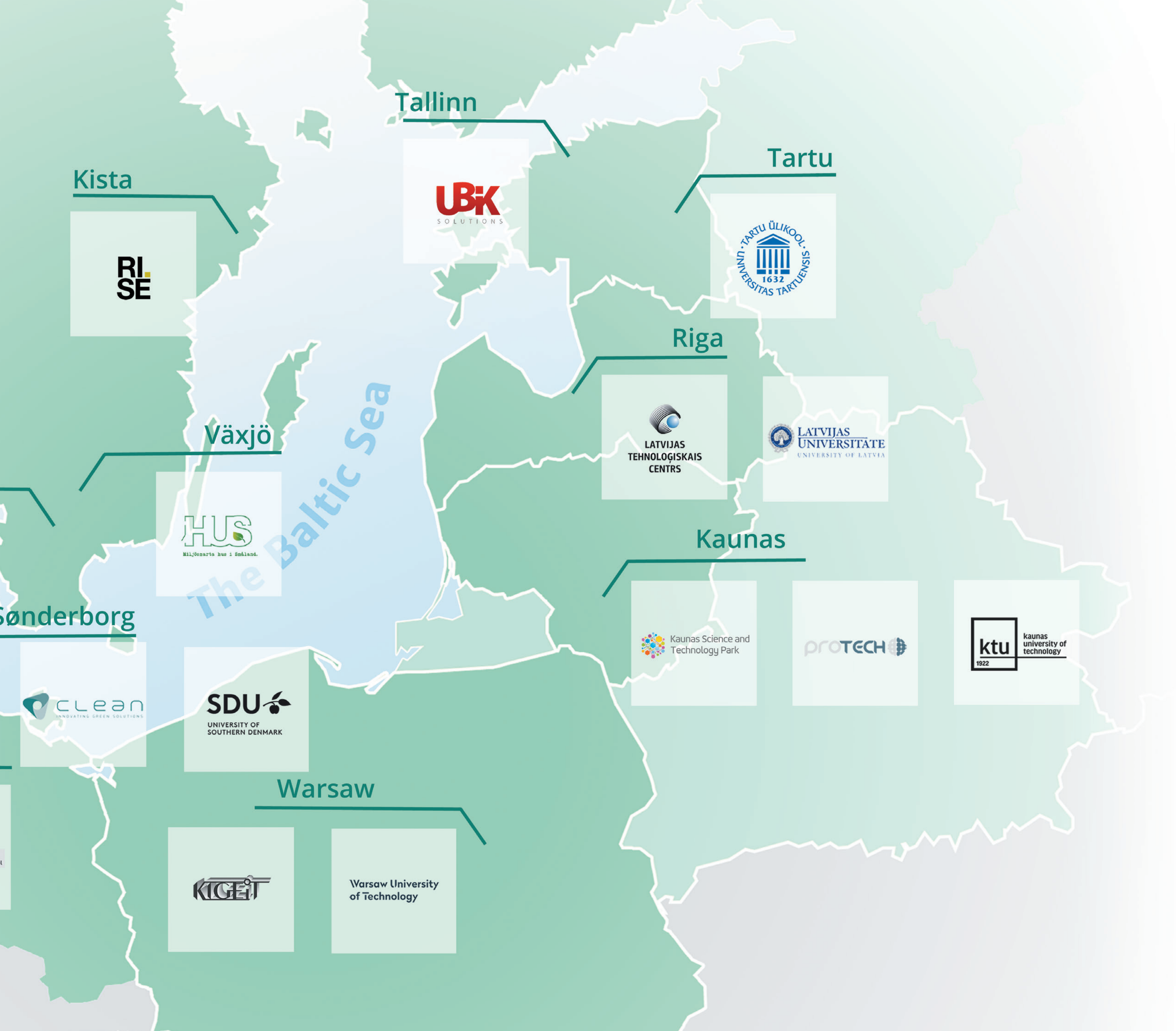
- 17 project partners: research institutions, companies and technology transfer organisations
- Duration from 2016 to 2019
- Budget: EUR 3.1 million
- European Regional Development Fund
- Interreg Baltic Sea Region Programme
- Led by University of Southern Denmark

Estonia

Indrek Jõgi, Head of the Laboratory of Plasma Physics, University of Tartu, Estonia:
“The BSR is a good region for collaboration on renewable energies: We have felt that during developing a photovoltaic test station on the top of the universities ‘Physicum’ in Tartu.”

Latvia

Dr habil. sc. ing. Janis Stabulnieks, Managing director, Latvian Technological Center, Latvia:
“Advanced power electronics is a rapidly developing field in the Baltic Sea Region, and the Green PE project has given a great opportunity to see what activities are taking place in other countries. It has helped finding the right people for collaboration and there have been many opportunities for testing out various application fields of advanced power electronics.”



ROADMAP
TOWARDS GREEN GROWTH

The use of wide bandgap (WBG) semiconductor materials facilitates revolutionary changes in power electronics and enables a drastic increase of electric energy conversion efficiency and power density of electric systems.
To foster the market uptake of WBG solutions, the Green PE project has produced two documents providing companies and decision makers in the Baltic Sea Region with valuable information about the market potential of advanced power electronics in the Baltic Sea Region and the world and their implementation feasibility in the region. Eight technology transfer partners from seven different countries provided small and medium-sized companies with these documents information on technical and economic opportunities as well as barriers. Thereby the international competitiveness of the companies is promoted.

1. Technology and product roadmap

The technology and product roadmap provides knowledge about the market potential of advanced power electronics based on WBG materials. The roadmap discusses aspects related to materials, devices and the most relevant application fields for the project's focus areas:

- Renewable energies
- E-mobility
- Smart houses

Toomas Plank, Director of the Institute of Physics, University of Tartu:
"According to a OECD report **[1]** from 2017, Estonia has the most carbon intensive economy in the OECD. So, Estonia needs to move faster towards a greener economy and APE has an important role in this movement."

Toms Stalmans, Project manager, Istabai, SIA:
"In Latvia, there are special regulations for the energy performance in buildings. In addition to usage of advanced isolation materials, it is important to introduce temperature regulation measures to save energy. The solution is to introduce smart house systems which increase the comfort level in houses."

The Estonian Renewable Energy Association [2]:
"The geographical location of Estonia and local weather conditions would enable to produce all energy needed in electricity and heating from renewable sources."

2. Regional specialisation document

The market uptake of power electronics for green applications is strongly influenced by local factors such as policies and regulations. Market drivers and barriers significantly differ between countries and regions. Therefore, the Green PE project conducted a regional analysis of relevant aspects influencing the market uptake of power electronics for green applications and provided a compilation of relevant factors at regions or countries participating in the Green PE project.

The information presented in the 'Technology and Product Roadmap' and the 'Regional Specialisation' enables small and medium-sized companies across the Baltic Sea Region to substantially improve their technology management, take informed decisions regarding research and development as well as market entrance investments and timely decisions. The implementation of new efficient power electronics will speed up the electrification and efficient use of electric energy in many application areas resulting in significant energy savings.

Dr sc. ing. Gaidis Klāvs, Director of the Institute of Physical Energetics, Latvia:

"The competitiveness of Latvian economy, energy security and energy sustainability are key issues for implementing the energy policy. Latvia has one of the largest proportions of renewable energy within the EU making up one third of Latvia's energy mix. Biomass and water are the most widely used renewable energy resources. Nevertheless, the policy is to further increase the usage of renewable energy sources, particularly also wind and solar energy. For transformation of different types of energy into electricity, advanced power electronics components are essential."

Mariusz Sochacki, Warsaw University of Technology, Poland:

"The most dynamically developed products are Polish electric buses. Everything points to the fact that these products will also be supported by large projects financed from EU and national funds. The Polish solar farms look most glaring on this background. We expect at most 300 MW of installed capacity and about 1 GW until 2020. The increase in installed capacity is primarily a consequence of the formation of large solar power plants as part of the auction system."

IMPACT OF THE NETWORKING

- so far over 240 companies actively involved in the project activities
- around 80 company visits (by the end of the project)
- around 45 workshops (by the end of the project)
- over 10 provided technology consulting projects
- 7000 companies accessed via tech transfer partners

PILOT ON E-MOBILITY

Often companies complain about potential barriers such as high costs of new components and high requirements for device materials. With its pilot on e-mobility, the Green Power Electronics project aimed to refute these prejudices through field tests with municipal garbage trucks and racing cars.
That required radically new vehicle electronics with a power train integrating components based on wide bandgap semiconductors such as silicon carbide (SiC) and gallium nitride (GaN).

Pilot actions

Project partner Converdan A/S from Denmark has designed a prototype energy-efficient, grid-connected battery conditioner based on SiC. In order to guarantee energy efficiency, charging and discharging is performed using high-voltage Li-Ion or LiFePO batteries with minimal of energy loss. This enables energy efficient conditioning of the batteries during daily charging, battery stack manufacturing and potentially for grid support in a smart grid installation.
The second part of the pilot was dedicated to the use of advanced semiconductor components in electrically powered racing cars. Within the pilot, the performances of Si and SiC-based inverters in an electric motor dynamometer with a permanent magnet synchronous electric motor (nominal power from ≥80 kW to ≤120 kW) and direct current power supply (system voltage from ≥400 V to ≤900 V) were compared regarding the

- inverter's power output
- inverter's efficiency as a function of output and input electrical power
- inverter's efficiency as a function of power module steady state operating temperature at the nominal motor power output level.

As a result, an electric motor drive prototype based on SiC components was designed and produced by the Latvian company Drive eO.

Donats Erts is the Director of the Institute of Chemical Physics at Green PE project partner University of Latvia which contributes to the E-mobility pilot with its expertise in testing and quality assurance of electronic devices.

What gaps did you aim to fill with the E-mobility pilot?

There are a number of technological hurdles that make the adoption of energy efficient and environmentally friendly transportation difficult. Materials like silicon carbide (SiC) are emerging in power electronics applications and provide a scope for improvement of the current electric vehicle propulsion systems. We saw an opportunity to relate the results of fundamental research to an everyday application of global importance and to demonstrate the advances that it can help to make.

Did the pilot results meet your initial expectations?

The pilot project was all about demonstrating how SiC power electronics can improve the traction systems that are used in every single electric vehicle worldwide. We managed to attract a partner that develops electric racing cars which provided us with an exciting demonstration platform and thereby increased the reach of this study.

Kristaps Dambis is the Project Director at the Latvian company Drive eO. Drive eO has been collaborating with the Green PE project consortium within the E-mobility pilot and has designed an electric motor drive based on SiC components.

Range, power costs, charging issues – did the project pilot show new aspects to overcome these concerns regarding electromobility?

Limited range is indeed a typical concern faced by everybody who is considering a switch to an electric vehicle. Although an average electric vehicle would serve the majority of daily transportation needs for the majority of people, it is still likely to be impractical for the long range or unplanned trip. The solution relies on progress in two areas – battery technology and the overall efficiency of drive train systems. The latter is exemplified by this pilot project where the efficiency of the motor controller was improved by adopting the latest SiC power module. Every little gain that contributes to the system efficiency is directly translated into a potential for a longer range of the vehicle.

What are the most valuable findings from the Green PE project's E-mobility pilot?

Most importantly, clear benefits of the experimental SiC power electronics as compared to conventional Si-based power modules were demonstrated. Back-to-back comparisons showed an increase in inverter efficiency from 92 % to 96 % within the test conditions. That was also reflected in lower steady-state operating temperatures (down from 48 °C to 44 °C) of the power module. Dynamometer testing provided us with data relevant for making further technical and commercial decisions. There is no doubt that SiC power electronics will soon be adopted into series production. It was also very valuable to establish a relationship with a new group of partners who have shown commitment to set up this initial study and continue with the advancement of electromobility.

PILOT ON RENEWABLE ENERGIES

The utilisation of new sources for renewable energies (large scale photovoltaics, offshore wind, and large scale bioenergy) requires radical changes in the power electronics modules on the element (e.g. transistor) level.

For achieving this, our project set up a demonstration pilot with a power converter with the highest light load efficiency for renewable energy application.

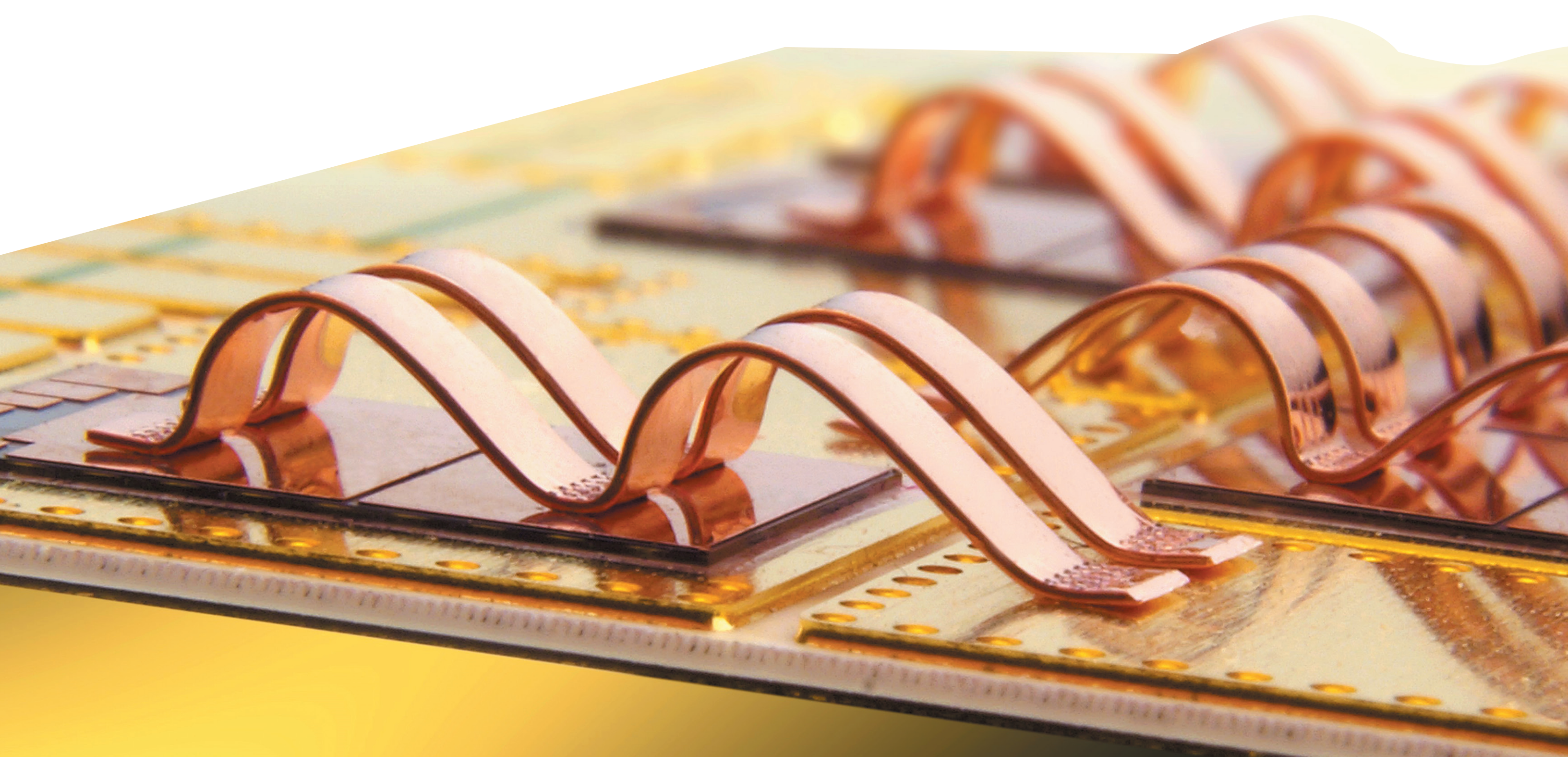
Pilot actions

Photovoltaics (PV) requires conversion of direct current (DC) from the PV panel to alternating current (AC). Conventional DC/AC inverters implement a huge battery of electrolytic capacitors while only a small fraction of the stored energy is used for the power decoupling at nominal working conditions of such a system. Power density can be increased dramatically by the application of an additional pair of gallium nitride (GaN) transistors creating an active power buffer (APB) circuit.

Within the pilot demonstrator, the team of the Warsaw University of Technology compared the APB design to a well-known electrolytic capacitor DC link mainly to define a voltage ripple threshold beneficial to promote the APB solution. All advantages of GaN transistors were exploited by the Warsaw University of Technology team to reduce the dimensions of a conventional 2 kW inverter and demonstrate the highest energy efficiency for the final solution.

At the same time, a dedicated inverter control system was developed to optimise the system operation. The pilot showed that it is possible to implement a 2 kW DC/AC inverter with a peak efficiency higher than 98 %. This very flexible solution can also be matched for other applications beyond the use in conversion of energy from renewable energy sources.

In the second pilot demonstrator, the team at the University of Kiel, has developed a high efficient PV-inverter. The 2,5 kW single phase prototype system is using wide bandgap switches and is based on a patented switching control algorithm, which insures a high efficiency over a wide power range – the peak efficiency is 99,5 %. Therefore, it uses only passive cooling, which offers a substantial advantage on the reliability and size of the solar inverter. The switching technology furthermore has also reduced the size of the passive filter components. The optimised algorithm – including MPP Tracking – was implemented on a commercial, cost effective microcontroller.



PILOT ON SMART HOUSES

Via this pilot, the project demonstrates the reliability and economic feasibility of advanced power electronics for smart building applications by maximising energy savings and cost reductions and increasing the use of locally produced energy.

Pilot actions

A demonstration system was set up at a plus-house in Växjö, Sweden, already equipped with solar panels and solar collectors. Integrated into everyday life in an ordinary private household, the pilot showcases the advantages of advanced power electronic solutions for the energy management in smart houses.

The house was equipped with energy storage capability and an additional DC appliance network supporting lighting, communication equipment and other appliances. The system is stand-alone with full islanding capacity in full service in a family house, meaning that the house's basic functions can work using locally produced energy in case of power outages.

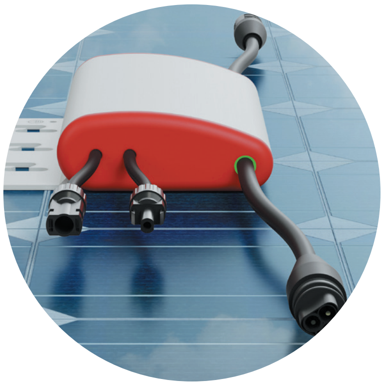
This concept offers:

- A solar system which is efficient, autonomous and maximises the consumption of energy produced in-house reducing the transactions with the power grid
- Increasing resilience in society as inhabitants are less vulnerable and more independent in case of power outages due to a direct storage of the generated energy in connected batteries
- Less variations in power and voltage in the local grid supporting stability in the grid

The new systems and infrastructure have been installed in addition to the standard equipment without interference and interruption of the power services.

As a second part of the pilot on smart houses, five photovoltaic test stations have been installed as a testbed for wide bandgap-based (WBG) devices and systems on the roof of the 'Physicum' at the University of Tartu, Estonia.

This pilot is meant to do a benchmarking of Silicon (Si)- and WBG-based power converters to demonstrate their efficiencies. The system has the capability to monitor the functioning of solar panels and inverters independently from the inverter producers' measurement systems.



In addition, all weather conditions are measured at the same site and are available for comparison over 20 years retroactively: http://meteo.physic.ut.ee/?lang=en.

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To get in contact with the Green PE project team you can also use the application form on our project website at:
https://balticgreenpower.eu/application-form/

IMPRINT

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Project Management and Realisation

DSN Connecting Knowledge Kiel, Germany

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Page 8: **[1] reference:**
OECD Environmental Performance Reviews: Estonia 2017,
http://www.oecd.org/estonia/oecd-environmentalperformance-reviews-estonia-2017-9789264268241-en.htm

[2] reference:
http://www.taastuvenergeetika.ee/en/

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