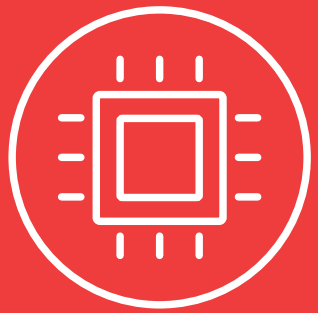
INDUSTRIES

HIGH TECH SYSTEMS AND MATERIALS (HTSM)



INDUSTRY OVERVIEW

In 2020 HTSM in Brabant consisted of 16,548 companies with 138,100 jobs. This means that more than one fifth of all jobs in HTSM in The Netherlands can be found in Brabant. The export volume in Brabant during 2019 was € 28.3 billion - which equates over fourthy percent of the Dutch export in HTSM is conducted in Brabant.

Within the HTSM sector, Brabant is by far the leading province in the Netherlands with regards to labor volume, production volume and added value. In terms of the total number of HTSM companies, only South Holland has a larger share – North Holland and Gelderland complete the top four.

HTSM	Companies	Jobs
Brabant	16,548	138,100
Netherlands	104,063	636,310
Share Brabant / NL	15.9%	21.7%

Source: Vestigingenregister Province North-Brabant 2020, edited by Fanion Research & Consultancy

THE INTEGRATED VALUE CHAIN HTSM BRABANT - INCLUDING A SELECTION OF COMPANIES

RESEARCH & DEVELOPMENT

- Altran (TASS)
- AME Applied Micro Electronics
- ASML
- DEMCON
- Malvern Panalytical
- NXP
- Philips Healthcare
- RAITH
- Sioux Technologies
- Thermo Fisher Scientific

- Dimenco

DESIGN & ENGINEERING

- AAE Advanced Automated Engineering
- Bradford Engineering
- DEMCON
- Frencken Mechatronics
- The MathWorks
- NXP
- Prodrive Technologies
- Proven Concepts
- VDL ETG, Enabling Technologies Group

- IME Elektrospinning

PROTOTYPING & INDUSTRIALIZATION

- ASML
- Ceratec Technical Ceramics
- NXP
- NTS Group
- Philips Healthcare
- Philips Innovation Services

- Incooling
- Lightyear
- SALDtech
- Smart Photonics
- Smart Robotics

COMPONENT & SUB-ASSEMBLIES MANUFACTURING

- Anteryon
- Frencken Engineering
- GKN Fokker Technologies
- KMWE
- NTS Group
- Teledyne DALSA
- VDL Group

- Additive Industries
- Leyden-Jar Technologies
- LionVolt
- SALDtech
- Smart Photonics

SYSTEM INTEGRATION

- ASML
- DAF Trucks
- Dasault Systèmes
- GEA Food Solutions
- Kulicke & Soffa
- Marel Poultry
- PlantLab
- Thermo Fisher Scientific
- HTSC (EAISI)

- Additive Industries
- LIQAL
- Pixelfarming Robotics
- PrecEyes

COMMERCIALIZATION

- ASML
- Bosch Security Systems
- DAF Trucks
- NXP
- Philips Healthcare
- PlantLab
- Signify
- Thales Cryogenics
- Thermo Fisher Scientific
- Vanderlande Industries

- PAL-V International

SERVICE & MAINTENANCE

- ASML
- Chromalloy Holland
- DAF Trucls
- DVC Machine Vision
- ENGIE
- Flowserve
- Philips Healthcare
- SPIE
- SPM Instrument
- Stork Thermeq

- LIQAL

(OUTSOURCED) SUPPLY CHAIN & SUPPORT CHAIN

Rhenus – O&M Movianto – DB Schenker – Systemair – Tjoapack – Neways Technology – IT&Care – Arnold & Siedsma – PerkinElmer / One Source – Axxicon Moulds – Bestronics – BKB Precision Bronkhorst Flow Technology – Ceratec Technical Ceramics – DEMCON – Eurofins Materials Science – Fujitsu Glovia – Gain Automation Technology – Goudsmit Magnetics – HighTechXL – The Gate KMWE Toolmakers – Mevi Advanced Technology – NTS Group – Philips Innovation Services – Sioux Technologies – TMC Group – Unicorn Industrial Cleaning Solutions Van Veghel Industrial Packaging – VanBerlo Goup – Xycarb Ceramics – YASKAWA

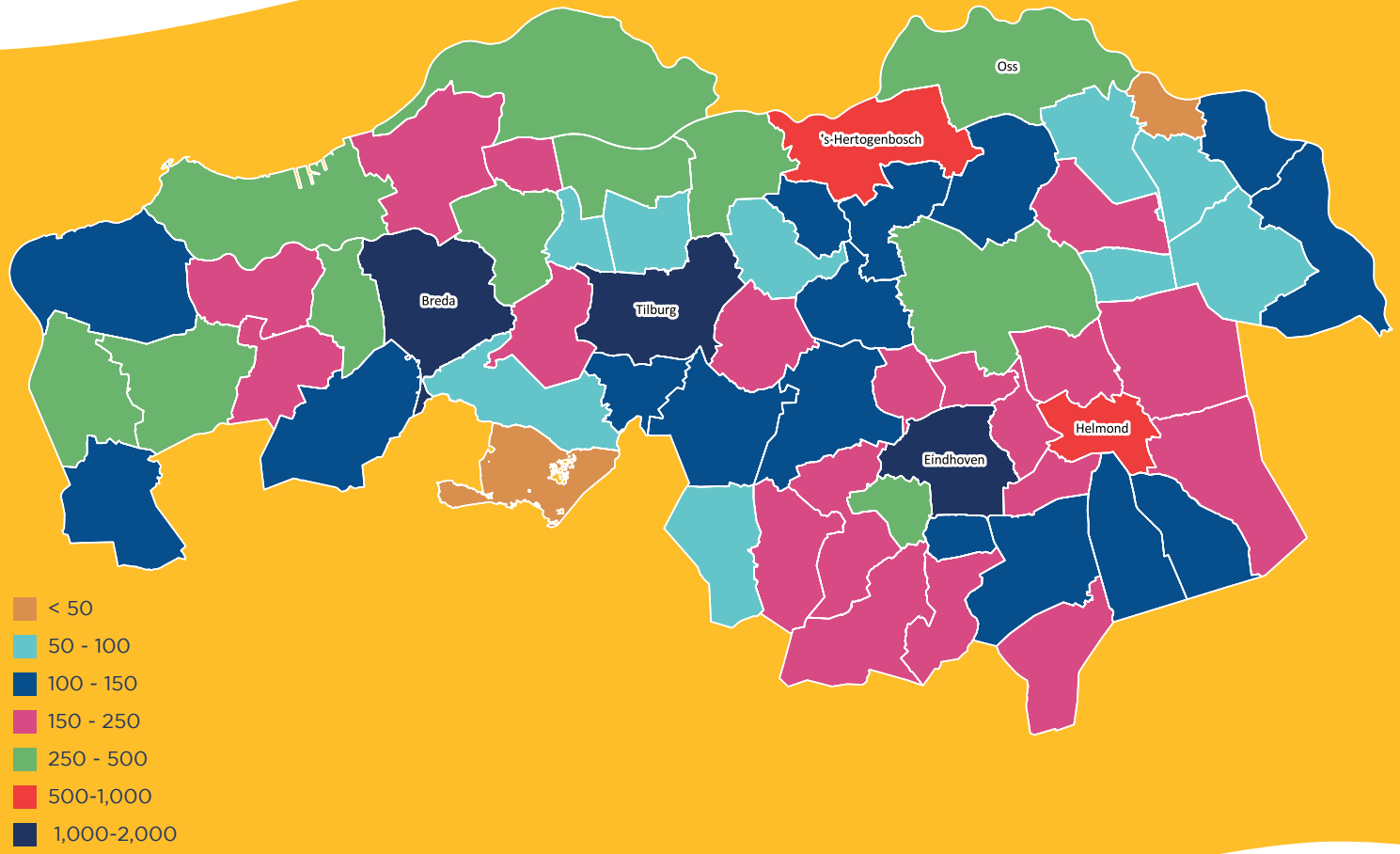
UNIVERSITIES, RESEARCH INSTITUTES & EDUCATION

TU/e, Eindhoven University of Technology – JADS, Jheronimus Academy of Data Science (a.o. Den Bosch) – Avans University of Applied Sciences (a.o. Breda) Fontys University of Applied Sciences (a.o. Eindhoven, Den Bosch) – Breda University of Applied Sciences – Holst Centre (Eindhoven) – Summa College – ROC ter AA Solliance Solar Research Institute (Eindhoven) – DIFFER Basic Energy Research Institute (Eindhoven) – EAISI Eindhoven Artificial Intelligence Systems Institute – Eindhoven Engine

Source: Engel – Een Heldere Blik helder@benengel.nl – +31 (0)652612671

- Start-up, scale-up or newly spun-off company
- High Tech Systems & Materials

NUMBER OF HTSM COMPANIES BY MUNICIPALITY



Source: Brabant Register of Establishments 2018, adapted by Fanion Onderzoek & Advies

PROMINENT COMPANIES IN BRABANT

Company	City	Product	Country
Anteryon	Eindhoven	Optical products	China
ASML	Veldhoven	Wafer steppers	Netherlands
BenQ	Eindhoven	LED screens	Taiwan
Bosch Transmission Technology	Tilburg	CVT, belts, pulleys and pumps	Germany
Canon	Den Bosch	Printers and Copiers	Japan
DAF Trucks Paccar	Eindhoven	Truck factory	USA
ECN	Eindhoven/Petten	Energy research institute; in Eindhoven esp. solar power + material testing facilities	Netherlands
IMEC	Eindhoven	Leading research in nanoelectronics, industry-relevant technology solutions in energy	Belgium
Intel	Eindhoven	Chips / processors	USA
KMWE	Eindhoven	Supplier for High Tech Equipment Industry	Netherlands
Medtronic	Eindhoven	Medical technology	USA
NTS Group	Eindhoven	Opto-mechatronic systems, modules and components	Netherlands
NXP	Eindhoven	Integrated circuits	Netherlands
Océ (A Canon Company)	Venlo (Limburg)	Professional printer equipment	Japan
Omron Europe	Den Bosch	Sensors, switches, optical devices	Japan
Opple Lighting Global	Best	Manufacturing LEDs	China
Philips Healthcare	Best	Medical equipment	Netherlands
ProDrive Technologies	Eindhoven	Complete high technology solutions	Netherlands
Ricoh	Den Bosch	Printers and Copiers	Japan
Signify	Eindhoven/Uden/ Roosendaal	Lighting	Netherlands
Smit Thermal Solutions	Eindhoven	Thermal equipment and processes	Netherlands
Thermo Fisher Scientific	Eindhoven	Electron Microscopes	USA
TESLA	Tilburg	Assembly electrical cars	USA
Vanderlande Industries	Veghel	Hoisting, lifting and transport equipment	Netherlands
VDL Bus & Coach	Valkenswaard	Bus manufacturing	Netherlands
Xerox	Venray (Limburg)	Printers and Copiers	USA

Source: BOM/Fanion research & consultancy

Talent High Tech Systems and Materials

HTSM is one of the strongest sectors within Brabant. Over 20% of the HTSM jobs in the Netherlands is found in Brabant. Brabant has a long tradition in educating talents in engineering and offers a broad infrastucture of schools, universities and colleges.

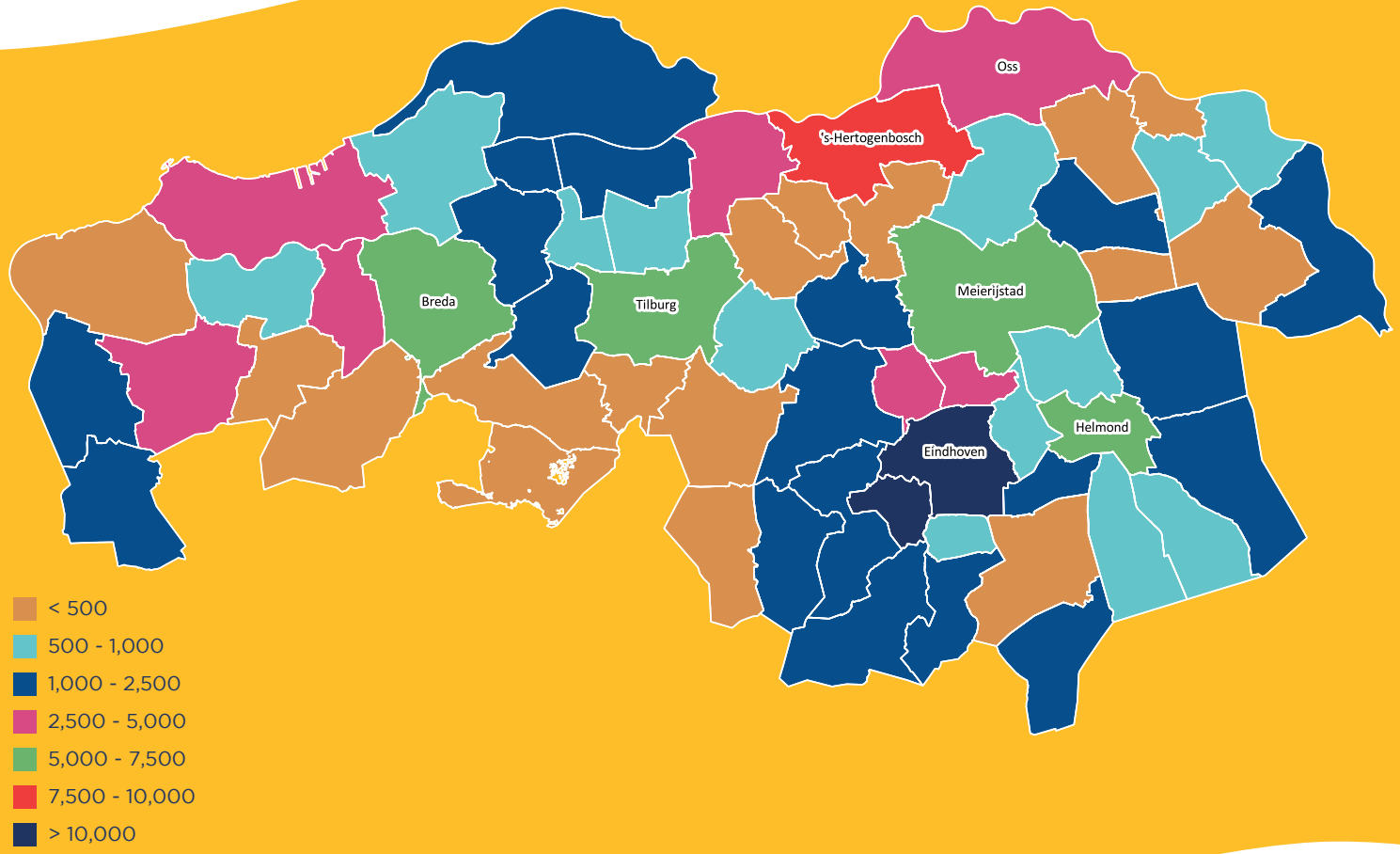
Workforce: employment in HTSM by education level

Students: number of graduates

Unemployment

HTSM	Companies	Jobs
Brabant	16,548	138,100
Netherlands	104,063	636,310
Share Brabant / NL	15.9%	21.7%

NUMBER OF JOBS IN HTSM BY MUNICIPALITY



Source: Brabant Register of Establishments 2018, adapted by Fanion Onderzoek & Advies

Workforce: employment

138,100 people working in High Tech Systems and Materials in Brabant. Over 46% has a higher education (UAS / University (BSc/MSc)), 38% has a medium education (HAVO/VWO/MBO) and 16% has lower education (primary school/ VMBO).

The Eindhoven/Helmond region accounts for most of the jobs in HTSM (74,330) of which almost 48% for personnel with a higher education.

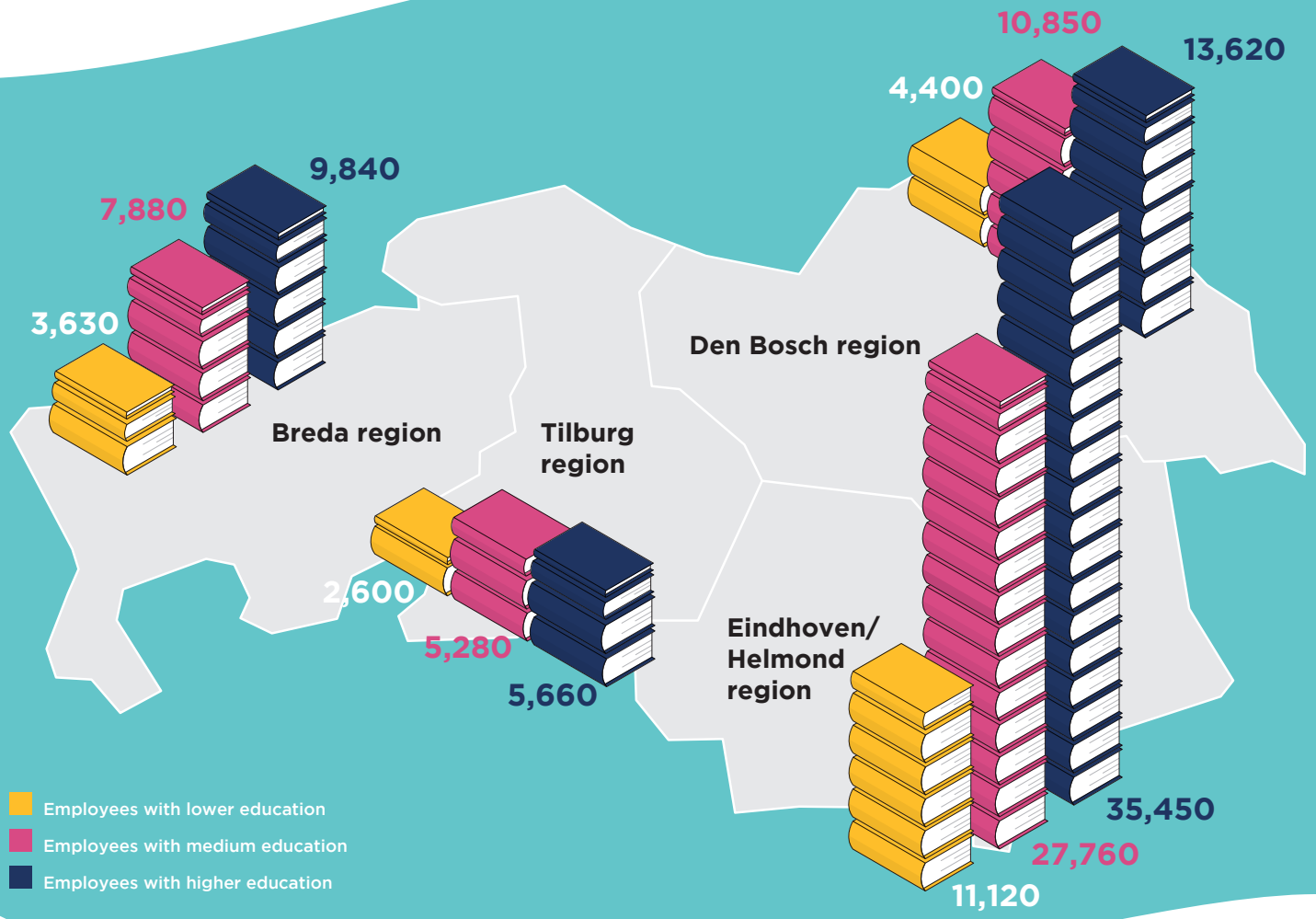
EMPLOYEES IN HTSM BY EDUCATION LEVEL AND REGION, 2020

HTSM	Total	Low	Middle	High
Breda region	21,350	3,630	7,880	9,840
Tilburg region	13,540	2,600	5,280	5,660
Den Bosch region	28,870	4,400	10,850	13,620
Eindhoven / Helmond region	74,330	11,120	27,760	35,450
Brabant	138,100	21,740	51,780	64,570

HTSM	Total	Low	Middle	High
Breda region	100%	17.0%	36.9%	46.1%
Tilburg region	100%	19.2%	39.0%	41.8%
Den Bosch region	100%	15.2%	37.6%	47.2%
Eindhoven / Helmond region	100%	15.0%	37.3%	47.7%
Brabant	100%	15.7%	37.5%	46.8%

Source: CBS, Vestigingenregister Noord-Brabant, 2020

NUMBER OF EMPLOYEES IN HTSM BY EDUCATION LEVEL



Source: CBS, Vestigingenregister Noord-Brabant, 2020

Graduates technical education

Graduates form the largest group of new people entering the labor market.

On a yearly basis there are 4,000 to 5,000 students graduating at a higher education level.

At the medium education level about 7,170 students graduated from a technical om HTSM education in 2019. Of this group 3,280 students graduated from a vocational HTSM education. 3,880 students graduated from secondary education of which most continue their education at a higher level at a UAS or university.

TECHNICAL STUDENTS AND GRADUATES AT HIGH EDUCATION LEVEL IN HTSM STUDIES, EINDHOVEN UNIVERSITY OF TECHNOLOGY

Students/Enrollments	2016	2017	2018	2019	2020
Bachelor	4,290	4,700	4,950	4,940	5,130
Master	2,080	2,210	2,430	2,710	3,160
PhD	1,440	1,530	1,560	1,570	1,650
PDEng	270	300	280	270	280

Graduates in HTSM	2015	2016	2017	2018	2019
Bachelor	520	620	740	880	920
Master	710	750	770	870	850
PhD	230	210	260	290	240
PDEng	130	110	130	120	110

GRADUATES IN TECHNICAL STUDIES, 2015-2019

UAS	2015	2016	2017	2018	2019
Avans UAS	1,240	1,260	1,260	1,300	1,460
Fontys UAS	260	340	300	300	290
Breda UAS	990	1,050	1,130	1,260	1,370
Total	**2,490**	**2,650**	**2,690**	**2,860**	**3,130**

GRADUATES IN SPECIFIC HTSM STUDIES

UAS: HTSM Studies	2015	2016	2017	2018	2019
Avans UAS	620	620	600	640	780
Fontys UAS	780	810	890	1,020	1,140
Breda UAS	150	210	210	180	200
Total HTSM	**1,550**	**1,640**	**1,700**	**1,840**	**2,120**

GRADUATES SECONDARY EDUCATION LEVEL, HTSM IN 2019

HTSM	MBO	HAVO	VWO	TOTAL
Breda region	650	320	520	1,490
Tilburg region	490	260	340	1,080
Den Bosch region	970	450	720	2,140
Eindhoven / Helmond region	1,180	510	770	2,460
Brabant	**3,280**	**1,540**	**2,340**	**7,170**

Sources: Jaarverslag TU/e 2020, Vereniging van Hogescholen, DUO

Currently 23,170 people with a technical background are seeking an new job. 74% (17,220) have a lower education, 20% (4,750 workers) has a medium education and only 5% (1,200 workers) has a higher education.

The Breda and Eindhoven/Helmond region have the largest pool of technical personnel with respectively 5,940 and 7,450 technical skilled people. In the Tilburg region and the Den Bosch region the supply is less extensive.

JOBSEEKERS WITH A TECHNICAL PROFESSION WITHOUT A CONTRACT, AVERAGE 2020

	Education level		
	Low	Medium	High
Breda region	4,320	1,310	310
Tilburg region	3,940	940	200
Den Bosch region	3,410	1,020	270
Eindhoven / Helmond region	5,550	1,480	420
Brabant	17,220	4,750	1,200

Source: UWV, 2021

REGIONAL STRENGTHS

THERE ARE THREE MAJOR STRENGTHS OF THE BRABANT REGION WITH REGARDS TO THE HTSM INDUSTRY

Concentration of a broad variety of companies

High R&D intensity

Logistic advantages

CONCENTRATION OF A BROAD VARIETY OF COMPANIES

Brabant is by far the largest province when it comes to HTSM in the Netherlands. Roughly one fifth of the companies, jobs and added value can be found here and one quarter of the total Dutch production volume in HTSM.

The ‘Brainport’ region is clearly the beating heart of Brabant when it comes to HTSM. Most of the large international operating companies such as Philips Healthcare, Signify, ASML, Thermo Fisher Scientific, Paccar DAF, VDL and NXP are established there. What’s more, many important HTSM companies are located elsewhere in Brabant.

Engineering and the manufacture of machines and equipment is the foundation on which HTSM in Brabant is built. The statement: “There is no machine that can’t be built in Brabant” is true. HTSM companies in Brabant build large hydraulic heavy-use machines for the off-shore and petrochemical industry and, at the same time, the smallest components on a nano-scale.

Brabant has a rich history in Mechanical Engineering and as a consequence the complete value chain is present in the region - from companies that specialize in basic parts comprising metal, ceramics, plastics to assemblers of equipment to designers of complex equipment and OEMs (Original Equipment Manufacturers). What’s more, the suppliers of the suppliers (Tier-2) are also well-established in Brabant.

The companies linked to the HTSM sector are also linked to different sub-sectors and different branches. The analysis of the 820 largest HTSM companies in Brabant shows that most of the companies are related to the Automotive (18%), Agri and Food (17%), Health (14%) and Construction (14%) sub-sectors. Connections with other sub-sectors are less frequent. These relationships are not exclusive. Most of these HTSM companies are active in several parts of the HTSM sector.

HIGH R&D INTENSITY

The region of Brabant is the driving force behind investments in R&D (research and development). The region has the highest score within the Netherlands, but also within Europe the region is performing very well.

Brabant accounts for over 30 per cent of total private R&D in the Netherlands and has the highest score on R&D conducted by businesses. The high private share of R&D leads to a higher applicability of innovations compared to other regions with mainly public-funded R&D.

In addition to the number of innovative companies (both OEMs and SME) with their own R&D departments, there are also many high class basic research and knowledge institutes in Brabant. These include the Eindhoven University of Technology (TU/e), TNO, the Holst Centre, imec, itri, ECN and TASS. The Netherlands, and Brabant in particular, are also known for their culture of open innovation. This means that they share R&D facilities and knowledge of key technologies that can be used in the different application areas.

Brabant owes this open mindset on innovation to the large OEMs that are present in the region but operate in different markets. These companies have the same interests in further development of the key technologies, but are hardly competitors when it came to applications.

Institutes like TNO and the Holst Centre are the main exponents of open innovation in the region.

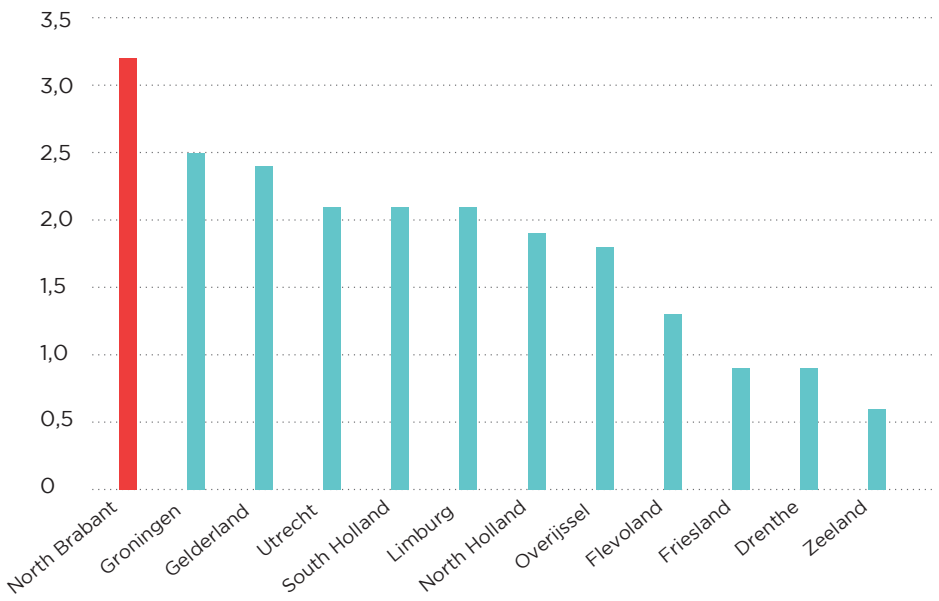
Brabant is the most intensive region in the Netherlands when it comes to R&D and one of the most innovative regions in Europe, as aptly illustrated by the following three facts:

1. **30% OF ALL INDUSTRIAL R&D IN THE NETHERLANDS IS UNDERTAKEN IN BRABANT**

2. **50% OF ALL EUROPEAN PATENT APPLICATIONS FROM THE NETHERLANDS ARE GENERATED IN BRABANT**

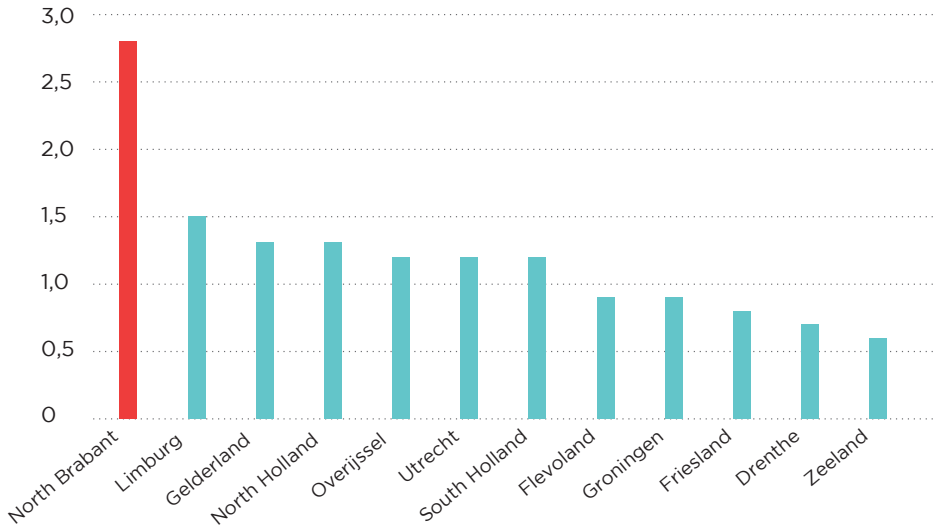
3. **BRABANT HOLDS FIFTH PLACE IN EUROPE FOR REGIONS WITH THE HIGHEST NUMBER OF PATENT APPLICATIONS**

R&D EXPENDITURE IN (PERCENTAGE OF RDP) IN 2018



R&D expenditure in business sector / regional domestic product

R&D EXPENDITURE IN BUSINESS SECTOR (PERCENTAGE OF RDP), 2018



Source: CBS (2021), bewerking Fanion onderzoek & advies

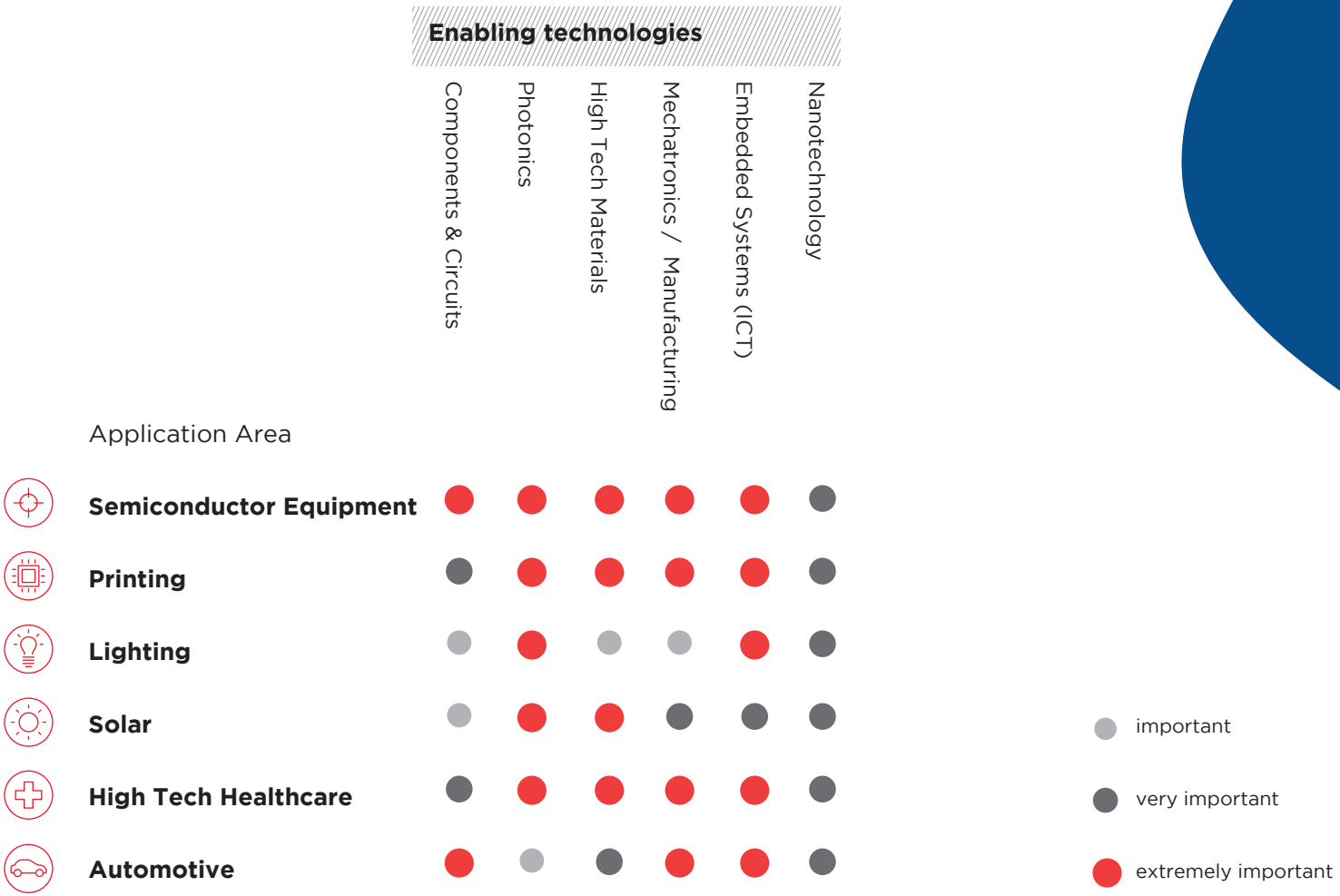
MOST IMPORTANT TECHNOLOGY AREAS FOR HIGH TECH SYSTEMS AND MATERIALS

In the Dutch agenda for HTSM there are 17 roadmaps appointed. These consist of seven enabling technologies (ICT, Nanotechnology, Components and Circuits, Mechatronics & Manufacturing, Photonics, Embedded Systems and High-tech Materials) and 10 application areas (Semiconductor equipment, Printing, Lighting, Solar (Energy), High Tech Healthcare (Life sciences & health), Security, Automotive, Aeronautics , Space and Advanced instrumentation).

In total there are 63 combinations possible.

ROADMAPS APPLICATION AREAS VERSUS ENABLING TECHNOLOGIES

COMBINATIONS APPLICATION AREAS AND ENABLING TECHNOLOGIES HTSM BRABANT



Finally, in the figure on the next page, a summary of the strengths and opportunities of the Application areas in HTSM in Brabant is provided.

OVERVIEW OF STRENGTHS AND OPPORTUNITIES HTSM APPLICATION AREAS IN BRABANT

	Strengths	Opportunities
Semiconductor Equipment	• Complete supply chain present with high class Tier 1 and Tier 2 • World leading position on Manufacturing Wafer Steppers • Knowledge mechanical engineering • IC design and production • Open innovation and R&D ecosystem	• Further miniaturization by Extreme UV etching /Double patterning • Security of ICs • High complex, low volume ICs • Photonic ICs
Printing	• Manufacturing specialized printing equipment • Knowledge mechanical engineering	• 3D printing • Printing on alternative substrates (Printed electronics, solar cells and LEDs)
Lighting	• World largest Lighting company • Long history on lighting • Knowledge LED technology	• Intelligent Lighting • Smart lighting systems • Smart buildings • Services
Solar	• Technological knowledge • Knowledge on mechanical engineering • Open innovation ecosystem	• Components and concepts for the built environment • Synergy with/in greenhouses and automotive • Knowledge exploitation, cooperation with other ecosystems
High Tech Healthcare	• One of the worlds largest manufacturers of medical equipment • Complete supply chain with high class Tier 1 and Tier 2 • R&D and open innovation ecosystem	• New medical equipment (improvement imaging and non invasive techniques) • Integrated services • Data collection and data analysis to improve equipment and services.
Automotive	• Concentration of broad variety of companies (Supply chain) • High R&D intensity • Logistic advantages	• Future powertrain: efficient combustion engines, electric drive, ligther constructions • Smart mobility: communicating cars, dynamic traffic management, vehicle dynamic controls

KNOWLEDGE INSTITUTES AND NETWORKS

Brabant offers an excellent environment for R&D and manufacturing activities. There is a high level of basic research undertaken in the region, embodied by the technical universities of Eindhoven, Leuven (Louvain) and Aachen. These are supplemented by high-class research laboratories such as Holst Centre, Nanolab@TU/e, Philips Innovation Services (MiPlaza), ECN, IMEC and Forschungszentrum Jülich.

HTSM UNIVERSITIES IN BRABANT

1. EINDHOVEN UNIVERSITY OF TECHNOLOGY (TU/E)

The facts and figures of the TU/e are:

- 13,690 students (2020/2021)
- 5,000 knowledge workers
- 90 nationalities
- 14 unique laboratories

SPIRIT OF COLLABORATION

Eindhoven University of Technology is a young university, founded in 1956 by industry, local government and academia. Today, that spirit of collaboration is still at the heart of the university community. The university fosters an open culture where everyone feels free to exchange ideas and take initiatives.

Eindhoven University of Technology provides academic education that is driven by both fundamental and applied research. Its educational philosophy is based on personal attention and room for individual ambitions and talents. TU/e's research meets the highest international standards of quality and the work produced pushes the boundaries of science. This puts TU/e at the forefront of various rapidly emerging areas of research.

Eindhoven University of Technology combines scientific curiosity with a hands-on approach. Fundamental knowledge enables the institution to design solutions for the highly complex problems of today and tomorrow. Its motto is: 'We understand things by making them and we make things by understanding them'.

The TU/e Campus is in the centre of one of the most powerful technology hubs in the world, Brainport Eindhoven. Globally, the university stands out when it comes to collaborating with advanced industries, as it has done with Royal Philips since its inception. Together with other institutions, TU/e forms a thriving ecosystem with one common aim – to improve quality of life through sustainable innovations.

TU/E HAS 10 RESEARCH DEPARTMENTS

I. Biomedical Engineering
II. Built Environment
III. Electrical Engineering
IV. Industrial Design
V. Industrial Engineering and Innovation Sciences
VI. Chemical Engineering and Chemistry
VII. Applied Physics
VIII. Mechanical Engineering
IX. Mathematics and Computer Science
X. Eindhoven School of Education

TU/E HAS 10 STRATEGIC RESEARCH AREAS

1. Artificial Intelligence
2. Smart Mobility
3. Energy
4. Engineering Health
5. Integrated Photonics
6. High Tech Systems
7. Complex Molecular Systems
8. Data Science
9. Humans and Technology
10. Smart Cities

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Established in the 1950s, the TU/e has always had strong values: optimism, collaboration, and a dedication to society. These values helped Brainport Region Eindhoven flourish and resulted in the university being ranked in first place by the Times Higher Education Ranking for collaboration with industry. Fifteen percent of the TU/e's scientific publications are created in partnership with industry, and the university has the highest number of part-time professors who work in industry in the country.

Societal challenges on health, energy and smart mobility are the driving force for the TU/e. Its research institutes, the Eindhoven Artificial Intelligence Systems Institute (EAISI), the Eindhoven Institute for Renewable Energy Systems (EIRES), the Institute for Complex Molecular Systems (ICMS), and the Institute for Photonic Integration (IPI), Eindhoven Engine, The Gate combine the strengths of the university with industry needs and government strategy. TU/e researchers play an important role in new products and companies in the Brainport Eindhoven area, in Brabant, and around the world.

The most important HTSM research groups in the TU/e are the following:

THE MOST IMPORTANT HTSM RESEARCH GROUPS IN THE TU/E ARE THE FOLLOWING: DEPARTMENT OF APPLIED PHYSICS

Research Group	Research topics
Advanced nanomaterials and devices	Research on new nanomaterial systems and investigating their properties (crystal structures, surfaces, size)
Coherence and quantum technology	The central theme is dilute matter at high phase space density. The goal is to exploit quantum coherence. The tools used include high power lasers and compact particle accelerators.
Elementary processes in gas discharges	Research on the elementary processes in gas discharges through a mix of theory, modeling, and the development of diagnostics.
Physics of nanostructures	Exploration of novel ways of controlling the electron spin and magnetic textures at the nanoscale for a wide range of applications.
Physics of semiconductor nanostructures	Research on the physics of individual nanostructures by investigating a wide range of available nano objects, ranging from the confinement in two dimensions to the extreme limit of zero-dimensional quantum dots.
Plasma & materials processing	The scientific objective of this group is to obtain an atomic-level understanding of the interaction of plasmas and reactive gases with materials in the field of atomic scale processing.
Theory of polymers and soft matter	Enabling a sustainable, functional, and resource-efficient next generation of materials by uncovering the physical mechanisms underlying the behavior of soft and biological matter.
Transport in permeable media	Research on understanding the physics of transport and phase changes in complex permeable media in order to develop
Turbulence and vortex dynamics	better materials for a sustainable society, i.e., materials for energy storage and technological porous materials. Research on the fundamental questions in fluid dynamics in an integrated approach.

DEPARTMENT OF MECHANICAL ENGINEERING

Research Group	Research topics
Control systems technology	The CST group develops new methods and tools in the area of systems theory, control engineering and mechatronics. The research focuses on understanding the fundamental system properties that determine the performance of mechanical engineering systems, and exploiting this knowledge for the design of the high tech systems of the future.
Dynamics and control	High-level research in the area of dynamics and control, with the emphasis on modeling, analysis, and control of mechanical and mechatronic systems.
Energy technology	This groups mission is to advance heat & flow technologies for energy and high tech applications. This mission encompasses the scientific development of new methods and tools (science); optimizing advanced systems (technology); transferring knowledge to application partners (commercialization); and educating and challenging future generations of engineers (education).
Polymer technology	The polymer technology group provides education on and conducts research in the broad area of polymer technology, i.e., the industrial arts of manufacturing of polymer-based products.
Power & flow	Power & Flow focuses on clean and efficient combustion and process technology, to cater for fast-growing energy demands.

DEPARTMENT OF ELECTRICAL ENGINEERING

Research Group	Research topics
Center for wireless technology Eindhoven (CWTE)	CWTE explores boundaries and explores new applications of wireless technology by creating a coherent, integrated approach to wireless systems, from the propagation of radio waves up to and including optical and wireless access networks. Our goal is to push boundaries and explore.
Control systems	Research on dynamic modelling and model-based control of complex dynamic systems.
Electromagnetics	Enabling 'electromagnetic engineering' by developing new modeling strategies for analysis and synthesis of a range of applications, e.g. antenna systems, medical electromagnetic stimulation, and metrology used in semiconductor manufacturing equipment. In order to do so, this group develops new facilities for experimental research in the area of antennas and wireless communications systems.
Electronic systems	This group creates constructive design trajectories for electronic systems that lead to high-quality, cost-effective systems with predictable properties (functionality, timing, reliability, power dissipation, cost).
Photonic integration	The goal is to provide major contributions to photonic integration and the associated applications, with a particular focus on indium phosphide technology.
Advanced network management and control	Research on the impact of emerging applications on the network and the effects that network impairments have on services. Our main focus is on cognitive Internet of Things communications.

DEPARTMENT OF MATHEMATICS AND COMPUTER SCIENCE

Research Group	Research topics
Applied analysis	The applied analysis group focuses on these mathematical disciplines and their application to the real world. This brings together many mathematical topics, such as differential equations, dynamical systems, variational calculus, functional analysis, geometry, and approximation theory.
Artificial intelligence	Artificial intelligence (AI) refers to apparently intelligent behavior in machines, distinct from human and animal intelligence. AI represents the general concept of intelligence, resting on technical pillars.
Scientific computing	Scientific computing is a fast-growing, highly interdisciplinary field that brings together methods from numerical analysis, high-performance computing, and various application fields. It is the area of research that provides better simulation tools aimed at many different applications.

OTHER DEPARTMENTS AND INTER-DEPARTMENTAL WORK

Research Group	Research topics
Department of biomedical engineering and department of applied physics	
Molecular biosensing for medical diagnostics	The MBx group develops technologies based on micro and nanoparticles for monitoring patients and treating diseases. With this goal in mind, the unique approach of MBx is to use advanced optical imaging techniques that quantify molecular processes with single molecule resolution within complex bio-macromolecular environments.
Department of Built Environment	
Building lighting	Major technology advances are enabling smart lighting solutions and LED technology is linking lighting technology to the digital world. This creates a wide range of new challenges.
Department of Industrial Design	
Future everyday	Future Everyday aims at bridging the gap between emerging technologies and everyday life: how to deal with uncertainties that come naturally with new and still evolving technologies, and how to translate them into meaningful products, systems, and services that seamlessly blend into everyday life.
Departments of Applied Physics and Chemical Engineering and Chemistry	
Molecular materials and nanosystems	The interdepartmental research group M2N investigates and develops functional molecular materials and nanosystems with tailored physical properties. Examples of applications are organic and polymer solar cells, light-emitting diodes, electrochemical and photovoltaic cells, and solar fuels.
Departments of Applied Physics and Mathematics and Computer Science	
Center for Quantum Materials and Technology Eindhoven	This group is part of a worldwide race to control the quantum states of elementary particles, and to integrate them in technology platforms. This so-called second quantum revolution will enable exponential advances in many fields of research and technology.

2. JHERONIMUS ACADEMY OF DATA SCIENCE (JADS)

The Jheronimus Academy of Data Science (JADS) is a unique concept in the Netherlands, which allows graduates to study, research and apply data science at three different Data Science Centres (TU Eindhoven, Tilburg University and Mariënburg Campus, Den Bosch) as part of the PDEng programme and to incorporate what they learn into existing ecosystems. The mission of JADS is to understand and further the value of data for solving complex societal and business challenges, with the academy serving as a linchpin between industry and the applied data science research conducted throughout JADS. The AgriFood industry is a Priority Industry to JADS, given that linking AgriFood to high tech by means of data communication, big data processing and artificial intelligence (AI) is one of society's challenges when it comes to sustainably feeding the world's growing population.

The Data Science and Entrepreneurship Graduate School turns out entrepreneurial and innovative data scientists who are just as good at performing cutting-edge scientific research as they are at applying it to the most pressing societal and business challenges. These graduates learn to operate in a collaborative ecosystem, fostering a stream of new scalable (or exponential) business models in Brabant and beyond.

The current JADS student body numbers 1,500-2,000 scattered across a range of programmes and three research centres.

JADS Jheronimus Academy of Data Science

APPLIED RESEARCH LABS

In the applied labs research focuses on how data science can be used in specific industries, creating specialist knowledge that can be applied directly, is in-depth and relevant.

- **DATA & AGRIFOOD**
  Fourth paradigm research and innovative crossovers between AgriFood, data and engineering in all its forms will be essential for feeding the world by 2050 while simultaneously reducing the environmental footprint of current food production systems. Solutions will only be created by working together.
- **DATA & HEALTH**
  Data & Health aims to bridge the gap between technical possibilities and practical ambitions. Exploring innovative methods for disease prevention, detection, treatment and follow-up. Advancing and accelerating learning capabilities within the full healthcare ecosystem.
- **DATA & CITIES**
  Data & Cities focuses on providing a novel perspective on the complexity of cities (and urban areas) by developing new data-based envisioning methods for *cities4people*.
- **DATA & SMART INDUSTRY**
  Data & Smart Industry uses data science to deal with the complex dynamics of production systems. Detailed real-time information allows the right product to be delivered to the right customer at the right time and at a minimal cost. Data science helps to improve the daily planning and monitoring of operations, is the basis for optimising production systems, and enables new concepts in the design of products and services.
- **DATA & SMART MOBILITY**
  Data & Smart Mobility aims to improve and perfect the way data is used from two perspectives – smarter connected vehicles and improved services surrounding mobility (such as *Maas*). The success and sustainability of these developments is greatly dependent on the quantity and quality of the underlying data.

FUNDAMENTAL LABS

The fundamental labs focus primarily on establishing and advancing the scientific side of data science:

- Computational Personalisation
- Dynamic Organisational Networks
- Jheronimus Academy Data Engineering (JADE) Lab
- Recommender Lab
- Digital Business Models & Ecosystems
- Ambitious Digital Entrepreneurship

JADS AND THE AGRIFOOD INDUSTRY: DATA-DRIVEN FOOD VALUE CHAIN MANAGEMENT

This JADS course connects the challenges faced in the AgriFood industry to the potentials offered by data science. Guest speakers from the TU/e and HAS University of Applied Sciences provide insight into the data-driven food chain: from precision agriculture to control engineering and marketing.

Students also receive lectures in the fields of AI (artificial intelligence), control systems, statistics and experimental design, sensing, data fusion and analytics and software engineering. They then use that knowledge to work on a current case, with the following options available: the business model of strip farming (multi-cropping), the smart pig value chain or the use of data in tomato farming.

The course provides students with a better understanding of the AgriFood industry and the available opportunities for creating value using technology and data science. They are required to review both existing and new business models and to seek out and exploit the opportunities on offer in an era of digitisation and sensing technology. From a teaching perspective it is a tough challenge to bring together these large and complex areas (Agriculture & Food and Data Science/AI), all of which are evolving globally at lightning pace. It is a major undertaking to get students to grasp the relationships and opportunities within such a short period of time. The course coordinators are Dr Rogier Brussee and Prof. Jakob de Vlieg.

THE JADS SME DATA LAB

The JADS SME Datalab helps companies create value through data by conducting short-term projects with professional and student data scientists. The students receive professional guidance from experienced professionals and scientists. Wherever a student hits a stumbling block, the JADS lab will always ensures that the project reaches completion.

The lab works together with its clients to define a data project with a concrete outcome. Preference is given to projects that deliver immediate savings or increased profits. Sometimes the client's aims extend beyond a single project, in which case we examine how a series of projects might produce the intended outcome.

A student spends about 60 to 80 hours on a project over six to ten weeks (depending on examination periods and other obligations). The JADS SME Data Lab charges a fixed price of 2,750 euros per project, part of which goes to the student involved in the form of remuneration.

3. FONTYS UNIVERSITY OF APPLIED SCIENCES

Fontys University of Applied Sciences has campuses in Eindhoven, Tilburg, Den Bosch, Helmond, and Veghel and focuses on five research topics:

- High-tech systems & materials
- Health
- Learning society
- Smart society
- Creative economy

Fontys is the largest university of applied sciences in the southern Netherlands. Its mission is to provide inspiring, challenging, and outstanding higher vocational education and to conduct practical research that is truly meaningful to society. Education and research at Fontys are directly in line with the current and future demands and needs of students, the professional arena, and (regional) society.

FONTYS FACTS AND FIGURES

- 477 bachelor's, master's, and other courses
- 44,320 students
- 34 programs in English
- 7,697 graduates per year
- 5,200 international students
- From 100 different countries
- 4,938 professional and educational staff

EMBEDDED IN KNOWLEDGE REGIONS

Fontys is embedded in the knowledge-intensive regions in the southern Netherlands, Brainport Region Eindhoven, Greenport Venlo/KennisAs Limburg, and Midpoint Brabant. The demand for highly qualified people in these regions is immense, and it is growing. A number of human capital agendas have been formulated to this end, which Fontys has helped to develop. Together with fellow institutions, companies, and industry, Fontys has developed living labs, professional workshops, centers of expertise, and other facilities. Students, lecturers, and researchers from a range of disciplines work together with industry professionals.

Fontys
University of Applied Sciences

FONTYS HTSM RESEARCH GROUPS

Research Group	Research topics
Additive manufacturing	Research topics are design guidelines for additive manufacturing, including the finishing and removal of support material, monolithic structures in additive manufacturing, and hybrid manufacturing technology.
Agrimechatronics	Technological applications for biological agriculture, increasing pressure on and poverty in the soil, and socially responsible and safe food.
Business Service Innovation **Big Data**	This group's objective is to increase the innovative performance of (small) companies through services. Big data science aims to provide insight into and create value from both structured and unstructured data.
Industrial Engineering & Entrepreneurship	Focus areas of the research are entrepreneurship, in particular entrepreneurship in technology, open Innovation, including collaboration between companies and collaboration with knowledge institutes, and operational excellence, or the continuous improvement of business processes.
Distributed Sensor Systems	Important research objectives are: Sensing: signal conditioning, data fusion Processing: signal processing: audio, video, Computing architectures: FPGA, SoC, embedded systems, real-time Actuating: human machine interfaces, cyber-physical systems, Interconnectivity: WIRED and wireless: IoT/IIoT, communication protocols
Future Powertrain	The main research topics are electric vehicle technology and advanced thermal propulsion systems.
High tech Embedded Software	The professorship focusses on two application areas – mobile robots and sensor networks. These systems are examined from a system perspective and four system aspects are identified, being architecture, integration and testing, modeling and learning, and software quality.
Centre of Expertise High Tech Systems & Materials'	FCE links higher vocational eduction with the business community, via research and joint development projects, and sharing knowledge.
Interaction Design	The interaction design research group is engaged in research into various aspects of gaming.

Source: https://fontys.nl/Innovatie-en-onderzoek.htm

Continued on next page >

FONTYS HTSM RESEARCH GROUPS

Research Group	Research topics
Mechatronics & Robotics	Fields of research are: Flexible Manufacturing: the flexible production of multiple products by a machine or robot, with as little changeover time as possible. Manufacturing Logistics: the use of mobile robots on the work floor to transport products between different machines or robots. Human-Robot Interaction: how humans and robots can work together. Precision Engineering: controlling machines quickly and accurately for, for example, installing components in the electronics industry.
Humanities and Technology	The Humanities and Technology research group studies the influence of people and technology upon each other and conducts hands-on research at the interface of technology and psychology
Serious Game Design and Technology	The Serious Game Design research group is engaged in research into various aspects of gaming. The group researches and comes up with new possibilities for the use of games in healthcare, culture, entertainment, and education.
Applied Natural Sciences	The special interest groups (SIGs) of Applied Natural Sciences are Thin Films & Functional Materials, Diagnostics & Test Development, Solar fuels, Polymers, Sustainable process technology, and Detection & Measurement.
Virtual Reality	The Fontys Virtual Reality Lab has state-of-the-art techniques in computer graphics, visualization and virtual reality. Here, new products or processes can be visualized on behalf of companies.
Smart manufacturing	This group devotes itself to disruptive technologies and their application in the manufacturing industry. Examples include the internet of things, artificial intelligence, connectivity, robotics, 5G, 3D printing, and autonomous mobility.

Source: https://fontys.nl/Innovatie-en-onderzoek.htm

4 AVANS UNIVERSITY OF APPLIED SCIENCES

AVANS University of Applied Sciences provides education and hosts research in ten different fields and across 13 locations in Breda, Den Bosch, Tilburg, and Roosendaal. AVANS has six centers of expertise and more than 25 research groups. These groups of researchers conduct practical research.

The total number **35,083 students** were attending AVANS in December 2020.

The **professional staff** contingent numbers **3,300**.

The Expertise Center for Technical Innovation (ETI) focuses on the creating technical innovations for a sustainable world and its overarching theme is the Resilient City: a livable, resilient, and sustainable urban environment.

All AVANS technical courses are a part of the ETI, and lecturers, researchers, teachers, and students conduct practical research through various research chairs into creating the Resilient City. This research is commissioned by companies and institutions.

Various research chairs and departments play an active role in the expertise center, creating forward-looking concepts and practical solutions for a more sustainable world. The ETI also collaborates with universities of technology, other colleges, and partner companies. The knowledge gained is shared and immediately applied in practice and in educational programs, so that students immediately become familiar with the new technologies.

The Expertise Center for Technical Innovation at AVANS has five research groups that have strong links to the HTSM sector. Seen on the next page.

RESILIENT CITY

The research chairs and departments cover various aspects of the Resilient City. It is of great importance that cities are readied for a sustainable future, thanks to increasing urbanization, the energy transition, and material scarcity and waste. An integrated approach is required for this transition. Accessibility, quality of life, sustainability, air quality, sound health, and economic vitality are all inextricably linked.

In addition, increasing urbanization and the changing composition of households pose environmental, infrastructural, and safety challenges. The ETI is seeking in areas such as the circular economy, robotization, and the creation of smart cities, being cities with, for example, highly developed public transport systems and online platforms that make urban administration more efficient.

avans hogeschool

THE EXPERTISE CENTER FOR TECHNICAL INNOVATION AT AVANS

Research Group	Research topics
Data Science & IT	Research on new, challenging practical data science solutions that contribute to the Resilient City. This includes the efficient storage and transport of data, correct processing of the data and, finally, securing the data, whereby the usability of that data is not jeopardized.
Built Environment	The focus is on integral design and development, Design-driven innovation where design is seen as the core of engineering, innovation-driven professionalization, the interaction between knowledge and concepts, and design-research methodology
New Materials and their Applications	Material transition and sustainability are spearheads in the New Materials research group, as is their application.
Robotization and Sensors	The research primarily focuses on new applications using innovative technology and pushing the boundaries, concentrating on a broad integration of technology. Design methodologies such as system engineering and sensory and control engineering play a role in this field.
Smart Energy	The research primarily focuses on new applications using innovative technology and pushing the boundaries, concentrating on a broad integration of technology. Design methodologies such as system engineering and sensory and control engineering play a role in this field.

Source: https://www.avans.nl/onderzoek

5. BREDA UNIVERSITY OF APPLIED SCIENCES

Breda University of Applied Sciences is a medium-sized, government-funded higher education institution, with over 7,000 Dutch and international students from around a hundred countries. The BUAS offers bachelor's and master's degree courses at a professional and academic level in the fields of games, media, hospitality, facilities management, logistics, the urban environment, tourism, and leisure and events.

For the HTSM industry, the research on gaming conducted at the BUAS is of particular interest.

The BUAS Games research program focuses on digitally enhanced realities (DER), new forms of human interaction in environments designed using games blended with big data, geo-data, simulations, robotics, and artificial intelligence (AI). The next generation of games and digital media products and services are designed and created in the CRADLE lab.

- *Entertainment games focuses* on game cultures and designing and creating video games. Students study the content of video games, the processes and tools for creating them, and the surrounding culture. Within this broad field there is a focus on issues relating to diversity, storytelling, interface design/ feedback, and puzzle design (using 'escape rooms' as a thematic entry point). The research team works closely with the international AAA video game industry.

- *Serious games focuses* on how games can be used to improve the performance of organizations and systems. Many industries and societal sectors are interested in harvesting the potential benefits of game technologies and game concepts. In this department, game technology (including VR and AR) and game concepts are designed, developed, and used to profit from the deep impact that they can have on professionals, teams, organizations, or complex systems. Application areas for serious games are spatial planning, logistics, sustainability & ecological systems, tourism, entrepreneurship, management, leadership, and change.

Breda University OF APPLIED SCIENCES

RESEARCH INSTITUTES IN HTSM IN BRABANY (SELECTION)

1. EINDHOVEN ENGINE

Eindhoven Engine accelerates innovation in the Brainport Region through challenge-based research in its public-private research facility at the TU/e Campus. Teams of the region's most talented researchers from industry, knowledge institutes and students work together in Eindhoven Engine research programs to deliver breakthrough technological solutions.

Eindhoven Engine unlocks the collective intelligence in the Brainport region. Thanks to a unique formula, innovators from companies can join forces with students and experienced researchers and staff of knowledge institutes in order to work together to accelerate innovation and create disruptive projects in which colocation is a prerequisite.

The Eindhoven Engine was founded by three knowledge institutes – the Fontys University of Applied Sciences, the TNO (Netherlands Organization for Applied Scientific Research), and TU/e, Eindhoven University of Technology, since 2020 the three shareholders of Eindhoven Engine BV. Other founding partners include the high tech companies Philips Healthcare, Signify, ASML, VDL, NTS, and NXP. These companies, extended with Brainport Industries and the shareholders form the Advisory board of Eindhoven Engine.

Eindhoven Engine is described in more detail in Chapter 8, section C under successful 'Public-Private Partnerships & Networks (P189)

2. EAISI - THE EINDHOVEN ARTIFICIAL INTELLIGENCE SYSTEMS INSTITUTE

The Eindhoven Artificial Intelligence Systems Institute (EAISI, pronounced 'easy') is a new institute of Eindhoven University of Technology devoted to the field of artificial intelligence (AI). Through EAISI, the university aims to contribute to the growing importance of AI in society, business, and science, and to meet the rapidly increasing demand for education, engineers, and expertise in the field of AI. The TU/e has been active in the field of artificial intelligence for decades, giving the new institute a very solid foundation.

The TU/e intends to invest 100 euros million in EAISI's education and research through to 2025, with the money primarily from the university. EAISI is aiming to attract a further 30 million euros each year from what are known as third-tier grants (the Dutch Research Council, EU, and other funders) and from the private sector. There are already about a hundred AI scientists working at TU/e, and the university wants to add a further 50 researchers, with a total of 150 people directly or indirectly involved in EAISI.

EAISI will focus on using data and algorithms in machines, such as robots, autonomous cars, and medical equipment. This field has always been an area of focus for the TU/e and Eindhoven Brainport region. The new institute will also study the interaction between humans and systems, including reliable and transparent methods for creating moral and ethical AI.

The TU/e has been active in the field of AI for years, conducting innovative research in the fields of intelligent machines, smart mobility, and healthcare. It has two leading institutes that are actively involved in studying AI and its applications – the Data Science Center Eindhoven and High Tech Systems Center.

PARTNERS

In keeping with the TU/e's traditional close ties to the private sector, EAISI has partnered with numerous companies and organizations at a regional, national, and European level. These include ASML, Philips, NXP, Brainport Eindhoven, the AI NL Coalition, 4TU.Federation, and EuroTech.

APPROACH AND OBJECTIVES

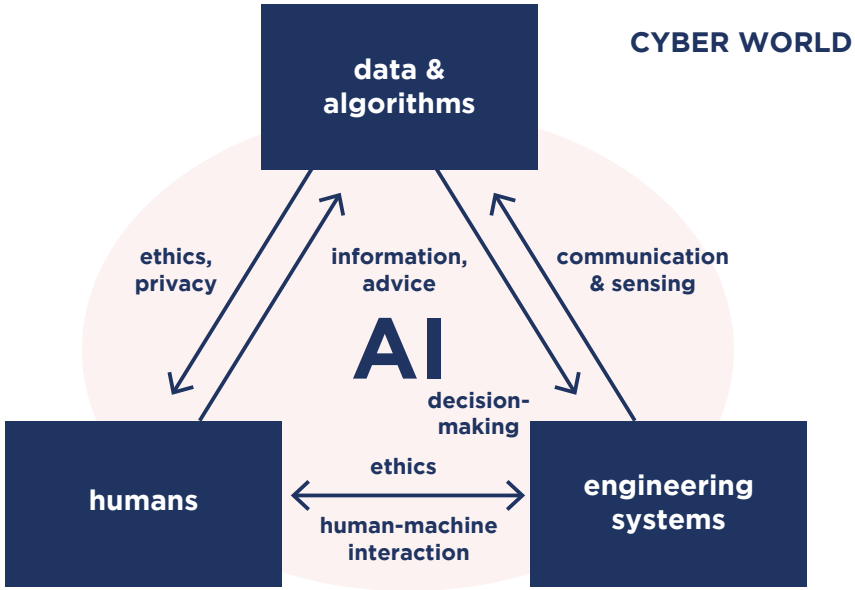
EAISI aims to develop AI technology for real-time autonomous decision-making in engineering systems that interact with humans. By focusing on engineering systems, the effect of AI technology will be in the real (physical) world, and generally in the presence and with the involvement of humans. Decision-making needs to be interpreted as any operational action for diagnosis, monitoring, and analysis, as well as control, task-performance and optimization of systems behavior.

TU/e
EAISI

These major challenges require expertise and contributions from different scientific disciplines. An integrated system view of AI will be developed in this multidisciplinary institute, with key contributions from three key domains:

a. Data and algorithms
b. Humans and ethics
c. Engineering systems

The research performed in the institute will generally be focused on the lower TRL levels 1 – 5/6, ranging from basic technology research to technology development.



Source: EAISI Mission & Vision

RESEARCH TOPICS

EAISI research will focus on the following three topics:

1. High tech Systems & Robotics:
   - Guaranteed machine performance
   - Autonomous machine operation and smart human-operator support
   - Multi-agent robotics
   - Predictive maintenance
2. Health Applications:
   - Improved diagnostics
   - Personalized and wearable health systems
   - Better understanding of personal health
   - Preventive health management
3. Mobility:
   - Vision and sensor capabilities for autonomous driving
   - Data analytics for effective transportation systems and distributed traffic management
   - Advanced driver assistance systems

AI AND STUDENT TEAMS

The TU/e is a breeding ground for young engineers that wish to address the challenges faced by society. These students participate in projects that combine education, innovation, and entrepreneurship that are funded by the TU/e and its sponsors. Several student teams use AI in their projects:

- Blue Jay: this team aims to create safe, interactive, and autonomous drones that can serve as autonomous assistants, both indoors and outdoors.
- Solar Team Eindhoven: the team focuses on sustainable mobility, working on a comfortable self-driving family car that maximizes the use of solar energy by efficiently consuming and sharing energy. The team has won the Bridgestone World Solar Challenge in Australia four times in a row.
- Tech United: Tech United competes in the autonomous soccer robots and autonomous service robots world championships, and it is the defending world champion in both categories.
- University Racing Eindhoven: URE builds high tech autonomous electric racecars for the Formula Student competition, constructing a new car each season.

3. HOLST CENTRE

The Holst Centre was launched in 2005 by imec (Flanders, Belgium) and the TNO (the Netherlands) and is supported by local, regional, and national governments. It is named after Gilles Holst, a Dutch pioneer in research and development and the first head of Philips Research. Located on the High Tech Campus Eindhoven, the Holst Centre benefits from, and contributes to, the state-of-the-art on-site facilities. The Holst Centre has over 200 employees from 28 nations and, has 56 industrial partners and has funding for 45 ongoing projects.

The Holst Centre is an independent research and innovation center that focuses on innovations for improving health and wellbeing and on guaranteeing sustainable environments. The institute bolsters its industry partners by developing world-class breakthrough technology solutions that can be marketed. To help solve global challenges, the Holst Centre links the Dutch Brainport region with a global ecosystem of industry partners and academia, allowing each sector to benefit from the other's expertise.

WIRELESS SENSOR TECHNOLOGIES AND FLEXIBLE ELECTRONICS

Combining expertise in wireless sensor technologies and flexible electronics means that the Holst Centre is in a unique position. The institution's partner companies value its ability to create demo models and prototypes and, using such a proof-of-concept, industrial partners transform the innovative technologies into new products and new manufacturing processes. The Holst Centre frequently takes technologies to a point where they are almost ready for market. Thanks to knowledge transfer, the Holst Centre contributes to the expertise and market position of its partners.

OPEN INNOVATION MODELS

The goal of open innovation is faster, cheaper, and more effective innovation, reducing risks and creating a rapid time-to-market for new products. At the Holst Centre, partners complement their in-house R&D with shared R&D, leveraging each other's talents and knowhow in a well-structured and professional environment. Outcomes generated at the Holst Centre tend to be shared on a non-exclusive basis between program partners, under agreements that are tailored to the needs and scenarios of each partner.

Where necessary, the Holst Centre also performs dedicated research in the form of a one-on-one agreement with a single partner. This is often done to speed up technology transfer and the industrial uptake of results garnered through such shared research, and which have reached a higher level of technological readiness. This working model also plays a role in partnerships with SMEs, which typically have more immediate R&D needs. Dedicated partnership and IP agreements are negotiated with these companies.

Holst Centre
Open Innovation by imec and TNO

HOLST CENTRE TECHNOLOGY SPINOFFS

- **Keiron (2020):** after many years of research, the Holst Centre has taken microelectronics printing to the next level. Laser-based printing technology is a contactless, digital, and laser-controlled technique for depositing both solid and liquid materials on any surface, including biomaterials, conductive adhesives, electronics, and metals. Laser printing allows complex functionalities to be added to chips, while microelectronics production processes are much faster and more precise. The technology equates to extraordinary opportunities for the mass-production of flexible electronics.

  Together with HighTechXL, the Holst Centre's TNO created a solid business case and a promising venture from the technology in the form of Keiron. This deep-tech startup provides a new direct-writing manufacturing machine for high-volume micro-manufacturing for microfluids and microelectromechanical systems (MEMS). The global market for laser-printed electronics has been estimated to be worth some ten billion euros by 2025.

- **LionVolt (2020):** thanks to an investment of 4.5 million euros from the Province of Brabant and the Ministry of Economic Affairs and Climate Policy, the Holst Centre's TNO has taken a significant step forward in developing its revolutionary 3D solid-state lithium-ion batteries. These batteries are made using the patented spatial atomic layer deposition (sALD) technique, and are intrinsically safe and light, recharge quickly, and have a long life.

  Major car manufacturers are keeping a close eye on progress, given that these batteries are a perfect solution for electric vehicles. The funding will be used to build a range of demo models for demonstrating that this promising technology is suitable for large-scale battery production. The Dutch government recognizes the importance of retaining this technology so that the Netherlands can maintain its strong competitive position in Europe. To further accelerate the development of this technology in the fast-growing battery market, the Holst Centre's TNO has created a spinoff company, LionVolt, dedicated to the 3D solid-state batteries

- **SALDtech (2018):** the Holst Centre has devoted over a decade to a new technology called spatial atomic layer deposition, which creates large-area ultra-thin layers. SALDtech, a Centre spinoff, was founded in 2018 to further develop, build and sell spatial atomic layer deposition (SALD) systems to the flat panel display industry. The SALDtech tool will help enable the production scaleup of next-generation display technologies. Related end-product display markets include smartphones, tablets, TVs as well as new form-factor displays in (autonomous) cars and on almost any surface. SALDtech has undergone numerous funding rounds and will use the money to develop and build production equipment.

HOLST CENTRE PARTNERS, 2019-2020

- Alpine
- Amore Pacific Group
- Analog Devices
- ARM
- Asahi KASEI
- Atlas Copco
- BAMBI Medical
- BASF
- BioTelemetry
- bloom
- China Lucky Group Corporation
- DAIJANG
- Datwyler
- DENSO
- DSM
- DuPont
- Faurecia
- FujiFilm
- GlobalFoundries
- Heliatek
- Henkel
- HITACHI Maxell
- Hugo Boss
- ILLUMIX
- Intrinsic ID
- Johnson&Johnson
- KANEKA
- LeydenJar Technologies
- LifeSense Group
- MegaChips
- Methods2Business
- Microsemi
- muRata
- Mitsubishi Chemical
- Nanogate
- NeuroPro
- New Cosmos Electric Co.
- NiKo
- Niraxx
- Novacentrix
- Onera
- Orange
- Orbotech
- OSRAM
- Packetcraft
- Panasonic
- Philips
- Pragmatic
- Renesas
- Rexroth Bosch Group
- ROHM Semiconductor
- Royole
- SABIC
- SALDtech
- Samsung
- Sekisui
- ShinEtsu
- SHINKO
- SILEX Inside
- Smart Floor
- SONY
- spgprints
- SUNPLUS
- technospark
- TEN Flecs
- touch biometrix
- VDL
- Water Future
- Water Link

4. SOLLIANCE SOLAR RESEARCH INSTITUTE

Solliance aims to use thin-film solar technology as an employment-driver. The research institute, a partnership between the TNO, imec, ECN, Holst Centre, TU/e, TUDelft, UHasselt, and FZJ, focuses on developing thin-film PV technologies and making them available to the private sector. Solliance links the worlds of science and commerce with the goal of creating sustainable energy.

The institute, which turned ten in January 2021, has made enormous strides, with the thin-film solar technology research a great success and with almost 180 scientists and a research budget of over 20 million euros to its name.

Solliance's industrial partners include CCM, DSM, Hanergy, Heijmans, Kameleon Solar, Monier, Panasonic, PolyPlastic, Rexroth, Rockwool, Shell, Solaris, SolayTec, and the VDL Group.

SOLAR RESEARCH
SOLLIANCE

RESEARCH PROGRAMS

Solliance Solar Research focuses on shared research. It works with industrial partners, universities, and research institutes, and shares facilities and knowledge as well as the risks inherent to the research. Learning from each other's perspective means that the research becomes more effective and that technology is brought to the market faster.

Every step in the value chain requires research in other disciplines, and it differs each time, from fundamental material and process research through to developing practical solutions in new applications. Three research programs have been created, each with their own roadmap but with a common vision:

1. Perovskite-based Solar Cells: the research focuses on creating perovskite solar cells and in particular on the lifespan, efficiency, and scalability of the production technology. The research is often of a fundamental nature.
2. Innovative Module Technology: for low cost/high performance and new applications, such as reducing absorber materials, fully adaptable monolithic interconnections on flexible substrates, and creating a cost-effective barrier and protective layer.
3. Application Integration Technology: aimed at the aesthetic use of thin-film modules in building materials, infrastructures, and vehicles, by developing technology for semifinished products and creating dedicated solar foils that can be seamlessly integrated in existing production methods.

THE POTENTIAL OF THIN-FILM SOLAR

Thin-film solar means that the layer of active material is many times thinner than in conventional solar panels, allowing solar cells to be flexible and making them less vulnerable to breakage and point load.

There is greater freedom in terms of form. The active material in traditional solar panels is silicon, which is into thin slices known as 'ingots'. These slices are about 200 microns thick and very fragile. The technology has been in existence since the 1950s and has evolved into an efficient and cost-effective way to generate renewable energy.

But the use of the material in thin-film solar is fundamentally different. The material, perovskite, copper indium gallium selenide (CIGS) or cadmium telluride, is simultaneously placed on a large surface using a printing or vapor deposition process. At a later stage individual cells are created, often in straight strips but also in other forms.

These two steps mean that thin-film solar cells can take on any form and be fully adapted to the requirements of the application. Solliance seeks solutions for integrating these thin-film solar cells into existing products or applications, such as vehicles or building materials. Because the shape can be adapted to the application, a much larger surface area can be clad with solar energy-generating foils.

5. DIFFER - THE DUTCH INSTITUTE FOR FUNDAMENTAL ENERGY RESEARCH

DIFFER research focuses on developing a clean, inexhaustible energy supply that available to anybody, anywhere in the world.

While the global climate changes due to fossil fuel emissions, the world's population – and the global demand for demand – continues to grow. The demand for sustainable and relevant energy solutions is high, whether for domestic, transport and industrial use.

DIFFER is helping to meet that demand through its fundamental scientific research into new and improved energy sources for the future. Research focuses on two major energy themes:

I. DIFFER researchers are investigating how the enormous potential of generating clean power from fusion energy can be achieved.

   The worldwide energy transition from fossil fuels to sustainable energy requires technology that allows large quantities of clean, sustainable, and reliable energy to be generated in compact power stations. Fusion energy could satisfy this demand without greenhouse gases being emitted. Nuclear fusion is the energy source of our sun, and in its core energy is released when hydrogen atoms react at high temperatures to produce helium. DIFFER strives to make this fusion process a safe and clean one on our planet.

   The first fusion reactor for demonstrating the technical feasibility of nuclear fusion as an energy source on Earth is now being constructed in the south of France. ITER (the International Thermonuclear Experimental Reactor) is a joint project between Europe, the United States, Russia, Japan, India, South Korea, and China, and is both larger and more complex than the International Space Station. DIFFER is the leading Dutch research center for nuclear fusion and the point of contact between Dutch researchers and companies that are part of the worldwide research into nuclear fusion. The research institute is the Dutch partner in the Horizon 2020 program EUROfusion and works with the Fusion for Energy EU body that is responsible for the EU's contribution to ITER.

II. Research is conducted into ways of converting sustainable energy cleanly and efficiently into fuel for storage and transport: solar fuels.

   Research conducted by DIFFER into solar fuels addresses the global challenge of efficiently converting sustainable energy into chemicals and storing it. This approach provides the greatest amount of energy and is ideal for the long-term storage and long-distance transport of sustainable energy. DIFFER focuses in particular on splitting water molecules (using sustainable energy generated by, for example, solar or wind power) into hydrogen and oxygen and the reduction of carbon dioxide (CO_2) to carbon monoxide as an important starting point for the synthesis of CO_2-neutral chemical fuels. The research involves the synthesis and design of novel materials and processes to obtain scalable, efficient, and cost-effective systems.

DIFFER

COOPERATIVE VENTURES

In order to achieve its goal, DIFFER works with industry and knowledge partners in a range of fields, including physicists, chemists, engineers, and other specialists. The organization aims to play a role in developing the technology required to generate and store sustainable energy as efficiently and cheaply as possible, using the right materials – enabling the acceleration of the transition to a sustainable society.

HISTORY

DIFFER was launched in 2012 as the focal energy research activity of the Dutch Research Council (NWO) as part of its Dutch Foundation for Fundamental Research on Matter (FOM). In 2017 FOM became part of a new body, merging with other NWO divisions. DIFFER grew out of the former FOM Institute for Plasma Physics Rijnhuizen into a multi-disciplinary national home for fundamental energy research. In order to optimize interaction with the broader academic world and to expand its facilities, DIFFER constructed an environmentally-friendly building on the Eindhoven University of Technology (TU/e) campus in the southern Netherlands. The institute moved to its new BREEAM-NL Excellent (sustainability-certified) building in May 2015.
International (research) staff

A broad spectrum of knowledge and expertise is represented at DIFFER, with physicists, chemists, engineers, and other specialists working together in multi-disciplinary teams that seek to accelerate the transition to a sustainable society. Some 90 scientists and 60 guest staff and interns work together at DIFFER, supported by 40 technicians and 30 support staff members. The global nature of the energy challenge is evident in the fact that our employees come from over 30 different countries.

RESEARCH FACILITIES

DIFFER's role as a national institute allows it to run research facilities that are beyond the scope of individual universities. These facilities help DIFFER to scale up the insights gained from fundamental research into ones that could have industrial applications. DIFFER's highly experienced engineers design, manufacture, and operate DIFFER's facilities.

Our mid-sized laboratory setups, Magnum-PSI and Ion Beam Facility, offer unique opportunities for researchers and partners, while well-equipped labs for optics or materials research are dedicated to research into solar fuels.

MAGNUM-PSI – MATERIALS UNDER FUSION-REACTOR CONDITIONS

Fusion reactors such as ITER and its successors will expose materials to intense heat and particle impacts when the hot plasma exits the magnetic cage and hits the exhaust wall. So a reactor wall must be designed that can withstand an environment as extreme as the surface of the sun. Magnum-PSI is the world's only laboratory able to test materials under conditions akin to ITER and future nuclear fusion reactors. An extensive set of diagnostics mean that changing materials properties can be studied in detail.

ION BEAM FACILITY – THE IN-DEPTH STUDY OF ENERGY MATERIALS

What happens to materials that are exposed to the extreme conditions in a nuclear fusion reactor? How can we improve the catalytic properties of materials and surfaces in chemical reactions? DIFFER's Ion Beam Facility is the only ion beam facility in the Netherlands. The 3.5 MV ion accelerator offers a suite of ion beam analysis techniques that allow researchers to characterize (sub-)surface material properties and investigate processes in materials for fusion energy, solar fuels, and others.

1. Magnum-PSI tests ITER wall materials, setting a world plasma fluence record.
2. overview of Magnum-PSI with the connection to DIFFER's Ion Beam Facility.