

SUSTAINABLE HOSPITALS

New Hospital Construction - Future Hospitals in Denmark

WHITE PAPER



About this white paper

This white paper presents the Danish approach to new hospital construction and includes a wide range of innovative solutions that contribute to creating sustainable healthcare for the future. It is part of a series of white papers that show how Danish solutions can contribute to increase efficiency in healthcare while empowering patients and staff.

Danish healthcare innovation is not exclusive for the Danes: many years of global presence show that our healthcare products and solutions create value internationally. Danish ideas and products are used every day in hospitals, medical clinics, ambulances, and nursing homes across the world.

We hope to inspire you and would like to invite you to Denmark to learn more about the Danish healthcare system.

Photo credits

- Foreword: Steen Brogaard (Minister for Health and Senior Citizens Magnus Heunicke), Danish Regions (Chairman of Danish Regions Stephanie Lose)
- Page 6: Top left: Adam Mørk, top right: Konsortium Indigo, below right: 3XN, Arkitema Architects
- Page 7: Top left: Herzog & de Meuron - Vilhelm Lauritzen Arkitekter, top right: C.F. Møller Architects, below right: KHPT I/S
- Page 8: 3XN and Arkitema Arkitekter
- Page 9: Kirstine Mengel
- Page 10: Niels Nygaard
- Page 11: Julian Weyer
- Page 12: Adam Mørk
- Page 13: 3XN and Arkitema Architects, BIM Equity
- Page 14: Top: Adam Mørk, Below: Niels Nygaard
- Page 15: Klaus Vedfelt
- Page 16: Systematic
- Page 17: Intelligent Systems
- Page 18: Mobile Industrial Robots
- Page 19: UVD Robots
- Page 20: Semi Staal
- Page 21: Rambøll
- Page 22: Hvidovre Hospital
- Page 23: North Denmark Region
- Page 24: Region of Southern Denmark
- Page 25: Getty Images/LSOphoto
- Page 26: Region Zealand
- Page 27: Grundfos
- Page 28: Health Innovation Centre of Southern Denmark
- Page 29: Konsortium Indigo
- Page 30: Health Innovation Centre of Southern Denmark
- Page 31: Wavecare
- Page 32: Chromaviso
- Page 33: PTR Robots
- Page 35: Franne Voigt (HRH The Crown Princess of Denmark)

Editor in Chief

Healthcare DENMARK, Anne Smetana, as@hcd.dk

Associate Editor

Healthcare DENMARK, Tina Lijndal Larsen, tll@hcd.dk

Steering Committee

Danish Ministry of Health, Martin Nyrop Holgersen, mnh@sum.dk
 Danish Regions, Kristian Taageby Nielsen, ktn@regioner.dk
 North Denmark Region, Niels Uhrenfeldt, niels.uhrenfeldt@rn.dk
 Region Zealand, Helle Gaub, hcg@regionsjaelland.dk
 Region of Southern Denmark, Torben Kyed Larsen, tk@rsyd.dk
 Danish Export Association, Thomas Andersen, tan@danishexport.dk
 Systematic, Jacob Gade, jacob.gade@systematic.com

Contributors



3XN, Stig Vesterager Gothelf, svg@3xn.dk
 Agitek, Jean-Paul Bergmann, jpb@agitek.dk
 Arkitema Architects, Birgitte Gade Ernst, bern@arkitema.dk
 Bim Equity, Ida Maria Sandgreen, reception@bimeqt.com
 CF Møller, Klavs Hyttel, KH@cfmoller.com
 Chromaviso, Ane Søby Eskildsen, ase@chromaviso.com
 Health Innovation Centre of Southern Denmark, Tina Nissen, Tina.Nissen@rsyd.dk
 Intelligent Systems, Kamilla Møller, kms@intelligentsystems.dk
 Mobile Industrial Robots, Rasmus Smet Jensen, rsj@mir-robots.com
 North Denmark Region, Anette Leth, a. leth@rn.dk
 North Denmark Region, John Schermer Stefansen, jost@rn.dk
 PTR Robots, Lone Jager Lindquist, ljl@ptr-robots.com
 Rambøll, Thomas Strecker Leitner, tk@ramboll.dk
 Region of Southern Denmark, Anne Sigh, Anne.Sigh@rsyd.dk
 Region of Southern Denmark, Helle Fjord Larsen, Helle.Fjord.Larsen@rsyd.dk
 Region Zealand, Poul Heller Bunde, pobu@regionsjaelland.dk
 Semi Staal, Helle Bugge-Hansen, hb@semistaal.dk
 State of Green, Charlotte Gjedde, cmg@stateofgreen.com
 UVD Robots, Per Juul Nielsen, pjn@uvd-robots.com
 Wavecare, Eva Wennerwald, ew@wavecare.com

Healthcare DENMARK's partners :

The partner logos include:

- MINISTRY OF HEALTH
- MINISTRY OF INDUSTRY, BUSINESS AND FINANCIAL AFFAIRS
- MINISTRY OF FOREIGN AFFAIRS OF DENMARK
- DANISH REGIONS
- Region of Southern Denmark
- NORTH DENMARK REGION
- Aalborg Kommune
- SDU
- AALBORG UNIVERSITET
- Confederation of Danish Industry
- DANSK ERHVERV
- DANISH EXPORT ASSOCIATION
- DANISH:CARE
- Falck
- SYSTEMATIC
- intelligent systems
- LEBA
- MIR
- UVD ROBOT
- OPENTELEHEALTH
- KMD
- Lyngsoe Systems
- WAVECARE
- icura
- CorporateHealth
- PRESSALIT
- University College

Executive summary



Growing demands, budgetary restraints and new patient expectations dramatically increase the need for healthcare services in Denmark. The solution to these trends are not just to build new hospitals, but to deliver healthcare in new ways, in order to make our healthcare system sustainable for the future.

The new hospital construction program aims to establish the future hospital landscape for Denmark, where our hospitals are designed to support our transformed, coherent and patient-centric future healthcare system. Digitalization and new technology, often driven by artificial intelligence and robotics, are critical enablers for the success of our future hospitals.

This white paper presents the key innovations and solutions which we believe are relevant to modern healthcare systems across the world.

Architecture and healing architecture

Healing architecture is becoming increasingly important in the healthcare sector's efforts to create environments that can stimulate patients' recovery and in attracting workers who thrive in the buildings. New hospitals across all the regions of Denmark are making use of the healing effects of light, air and pleasant surroundings, both inside and outside the buildings. Single-bed rooms are another design feature that not only help patients recover faster, but also have financial benefits, as hospital infections and medication errors are reduced. The results of these endeavors can be seen in the BoerneRiget children's hospital, where users were involved in planning-stage VR sessions, and in the new psychiatric hospital in Vejle, which has seen a 50% decrease in physical restraint measures.

Hospital logistics

While the highly specialized functioning that is typical of the new Danish hospital landscape has been instrumental in significant productivity increases, it also involves very high logistical demands. Efforts to reduce patients' length of stay and to coordinate patient flows and logistics are being helped by just-in-time solutions and the use of data for novel technologies, such as robots and artificial intelligence. One Danish region has introduced a system that forecasts occupancy for a week ahead and provides an over-

view of total capacity, allowing the coordination of patient flow, including in each specialty, and even between hospitals. In another region, a central cleaning facility has raised productivity and hygienic standards for beds, mattresses and assistive aids.

Sustainable buildings and environmental challenges

In keeping with Denmark's ambitious energy policies, the healthcare sector is meeting the demands posed by climate and environmental challenges through strong initiatives to reduce the footprint of its construction and operation. Wherever hospitals are being built or renovated, focused efforts are being made, often as part of public-private partnerships. Solar energy is being tapped at one new university hospital, while elsewhere, the world's largest wastewater treatment plant has been constructed. Other local solutions have found that energy audits can help finance new projects, while an eco-labeled hospital laundry has drastically reduced plastic waste by using thinner linen covers.

User-driven design and innovation

The focus on high quality, combined with efficiency, will continue to bring innovation to Danish hospitals by involving patients and staff in the development and implementation of new solutions. A few examples can be given here of the many successful initiatives from across the country:

Involving psychiatric patients in designing the features of a new type of bed has reduced self-harming behavior and brought more comfort to admissions. An ergonomic lighting system demonstrates the high priority given to patient safety and the work environment in operation rooms at a university hospital. Delivery rooms with a less clinical feel have a soothing effect on both birthing women and staff.

In another innovative project, the high costs and limitations of conventional patient transfer solutions were overcome with the introduction of a robot.

We hope you will find inspiration in the innovative concepts and technology cases described in this white paper, which aims to give an impression of Danish hospitals' role in a coherent and integrated healthcare system of the future.



• Magnus Heunicke
Minister for Health and Senior Citizens



• Stephanie Lose
Chairman of Danish Regions

Foreword

● Denmark has a modern and efficient healthcare system with free and equal access for all. This is something we need to preserve for coming generations. Therefore, Denmark has invested approx. EUR 6.5 billion in a new hospital structure that will be the physical pillar in the Danish healthcare system of the future.

By building new, modern, and innovative hospitals with state-of-the-art equipment and highly specialized treatment, we can continue to raise treatment-quality in hospitals. Furthermore, these hospitals are an integral part of the coherent and patient-centred healthcare system we continuously improve, and they will be hospitals fit for the medical needs of the future, but also for the healthcare professionals and patients that will use them.

Denmark has the perhaps most digitalized healthcare system in the world. Our digital

infrastructure allows patients to access their own health data online from anywhere, and the healthcare professionals have access to relevant data across the different sectors of the healthcare system. This digital infrastructure opens for a fundamental change in the way healthcare is provided - and our hospitals are part of it.

We use the digital infrastructure to enable patients to be active partners and to be treated in the primary sector, closer to and in their homes, instead of in hospitals. We know that by making the patient an active partner the results of treatment improve. At the same time, it allows the hospitals to focus on specializing in treatment only possible at hospitals, and it frees up resources in the healthcare system to provide extra care and attention to those patients needing it the most.

In an increasingly digital world where chronic diseases and changing demographics define





















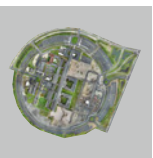









future treatment needs and challenge our healthcare systems, this is how we imagine that the healthcare systems of the future will look like.

We believe that these hospitals represent the future of hospitals in modern, coherent and sustainable healthcare systems. We are therefore proud to present this white paper on the innovative new Danish hospitals and we hope you will be inspired reading it.

Magnus Heunicke

Stephanie Lose

Index

<p>3 Executive summary</p>		<p>4 Foreword</p>		<p>6 New hospital construction in Denmark</p>	
	<p>8 Healing architecture optimizes the well-being of both patients and staff</p>		<p>9 Single-bed rooms improve patient recovery and staff workflows</p>		<p>10 Visionary design supports psychiatric hospital patients' recovery</p>
<p>11 A next-generation patient-centered hospital</p>		<p>12 The North Wing: Healing architecture for the future</p>		<p>13 Involving users and VR in designing a new children's hospital</p>	
	<p>15 High performance hospitals with innovative logistics solutions</p>		<p>16 Optimizing capacity management with intelligent hospital planning</p>		<p>17 Aalborg University Hospital improves sample quality with an intelligent sortation solution</p>
<p>18 Artificial intelligence improves hospital robot traffic</p>		<p>19 Robots disinfect hospital with ultraviolet light</p>		<p>20 Automation of cleaning processes improves hygiene and ergonomics</p>	
	<p>21 Automated service village improves hospital logistics</p>		<p>22 Sustainable hospitals and environmental challenges</p>		<p>23 District cooling of New Aalborg University Hospital</p>
<p>24 Solar cell park at New Odense University Hospital</p>		<p>25 Plastic recycling at hospital provides both environmental and economic benefits</p>		<p>26 Energy services project improves energy efficiency at new university hospital</p>	
	<p>27 State-of-the-art wastewater treatment plant at Herlev Hospital</p>		<p>28 User-driven design and innovation</p>		<p>29 Promoting collaboration and innovation through physical integration</p>
<p>30 Users design their own psychiatric bed</p>		<p>31 Innovative sensory concept at new mother-child department</p>		<p>32 Ergonomic hospital lighting improves minimally invasive surgery</p>	
	<p>33 Taking patient handling and rehabilitation to the next level</p>		<p>34 Danish hospital construction for the future</p>		<p>35 About Healthcare DENMARK</p>



• Top left: North Wing at Rigshospitalet (@ Adam Mørk), top right: New Aalborg University Hospital (@ Konsortium Indigo), below left: New Odense University Hospital, below right: Børneriget – Children’s Hospital Copenhagen (@ 3XN, Arkitema Architects)

New hospital construction in Denmark

● Danish healthcare is undergoing rapid transformation to meet patients’ changing needs. More healthcare services will be provided in primary care and through outpatient treatment. Therefore, future hospitals will play a very different role as part of an integrated and coherent healthcare system. A restructured healthcare sector with new and innovative hospitals is the key to creating sustainable healthcare for the future, with patients in an active role.

Danes enjoy the benefits of a universal healthcare system based on the principle of free and equal access for all. Its high-quality services are mostly paid from the public purse. Only a minor part of health expenditure is out-of-pocket payments, primarily for dental care and prescription drugs.

The Danish healthcare system is committed to ensuring a focus on patients’ needs. As more and more people live with multiple chronic conditions that require management and treatment, their medical needs will change. Modern technology enables us to treat patients much closer to home, and even in their homes, rather than in a hospital. Patients can take an active role in the management or treatment of their illness, while health professionals provide optimal care. We know that hospital admission brings disruption and distress to patients’ daily life, and the positive effects of technology affect not only quality of life, but also quality of care and treatment.

Treatment in hospitals will, of course, still be needed. Patients will expect medics to be highly specialized, in order to ensure the best outcome with the least disruption to their

lives. The Future Hospital Program is the response of the Government and Regions of Denmark to these expectations. An investment of approximately 6.5 billion euro (2018 prices) in 16 new “super hospitals” will bring us there.

All facilities will be designed for the people using them – patients and healthcare professionals. This means individual rooms for patients, hi-tech data-driven logistics systems, state-of-the-art technology, flexible multipurpose rooms and a building design to match.

Denmark’s hospital infrastructure will change – with fewer but larger hospitals, reducing the number of emergency departments from 40 to 21. In return, the new, more highly specialized hospitals will have stronger professional environments that can



• Top left: North Zealand Hospital (@ Herzog & de Meuron - Vilhelm Lauritzen Arkitekter), top right: Aarhus University Hospital (@ C.F. Møller Architects) below left: Regional Hospital West Jutland, below right: Zealand University Hospital (@ KHPT I/S)

handle even the most critical and complex cases, in terms of both competence and equipment. All catchment areas with more than 300,000 inhabitants will thus be covered for all major specialties and will offer 24/7 emergency ward services.

The Future Hospital Program is a key component of a major structural and organizational reform of the Danish healthcare sector to establish sustainable services, with hospitals playing an integral role in a coherent healthcare system that supports patients as active partners in their treatment, while at the same time meeting future healthcare requirements.

Facts

The national aim of replacing a significant fraction of hospital admissions with outpatient treatment will allow hospitals to focus their highly specialized services on treating the critically ill or injured. The primary healthcare sector will be tasked with offering less specialized and less intrusive treatments at a lower cost.

It is crucial that the design and use of the new hospitals lead to improvements in healthcare and treatment. Transformation should be ensured, not only by constructing newer and larger buildings, but also by designing the hospital environment of the future in ways that support a new model of care.

Vision for hospital construction projects

Focus on patients: Quality levels must be raised by building with a focus on patients and their safety, and by optimizing workflows

Improved efficiency: Efficiency should be improved by ensuring greater cohesion in patient treatment; new technology and innovative organization and procedures

Flexible hospitals: Flexibility must be ensured by enabling the extension or conversion of facilities and rooms without major expense



Healing architecture optimizes the well-being of both patients and staff

In Denmark, research results show that the principles of healing architecture such as light, sound, nature, colors and art can support patients' recovery and even contribute to a faster recovery. It also helps patients gain more control of their own situation, and creates a healthy work environment for the staff.

With many new hospitals being built in Denmark over the last decade, the concept of healing architecture has reached a higher level as it has become an integral part of architectural design.

As research has shown that well-designed environments contribute significantly to the healing process, several aspects should be considered in creating the optimal architecture for a hospital. Among these are: enabling easy physical and visual contact with nature, securing ample daylight and creating spaces that offer patients a choice between privacy and social interaction. Patients' safe-

ty and healthy work environments are other priorities.

No two hospital construction projects are alike, and great expertise is required to custom-design each building to fit into the natural surroundings with consideration for the building's functions. This is illustrated by Vejle Psychiatric Hospital, where good oversight and safe spaces for patients and staff are a focus point. This has proven to have a significant effect, as physical restraint measures and isolation of patients have seen a drastic fall. The design of BoerneRiget, by 3XN and Arkitema Architects, the future national children's hospital in Copenhagen is another example of how design can create a home-like ambience for children and parents that allows for play and makes the stay as close to normal life as possible.

Measuring the effect of healing architecture

Several factors must be considered when attempting to identify elements that support a

successful course of treatment. While a patient's recovery is the result of many individual acts of treatment and care, whose individual contributions are difficult to measure, peer reviewed research has established the positive effect of architecture on the healing process.

Evidence-based practices have established the effect of the architecture of a healthcare building on a number of outcome areas, such as efficiency, stress and fatigue among staff and patient safety, stress and well-being, as well as overall clinical results.

The Danish healthcare system is focused on further improvement and on creating even better hospitals. By focusing on healing architecture, the goal is to ensure that treatment in Denmark will continue to achieve excellent results using both outstanding clinical practices and well-planned, well-designed buildings.

Single-bed rooms improve patient recovery and staff workflows

In new Danish hospitals, all patient rooms are designed as single-bed rooms. This is a necessary priority to ensure a high level of hygiene, support patient empowerment and independence, as well as enable effective, high-quality treatment and encourage shorter length of stay.

Providing single-bed rooms for every patient is a cornerstone of all new hospitals being constructed in Denmark. A wealth of evidence supports the decision to make this a mandatory feature: patients recover faster,

as it is easier to achieve privacy and involve the family, but there are also financial benefits.

With only one patient per room, hospital infections and medication errors are effectively reduced. The undisturbed calm provided by single-bed rooms allow patients to sleep better, often decreasing the need for painkillers and sleeping medicines. As a result, many treatments can be performed without moving the patient, admissions are shorter, and the pressure on special examination rooms is reduced.

Single-bed rooms have brought many new benefits, such as enabling teleconferencing from the patient's room for communication with primary healthcare services and bedside handling of medication, thus preparing patients to coping on their own after they are discharged. Overall, the possibilities for individual planning of care routines are greatly enhanced.





Visionary design supports psychiatric hospital patients' recovery

● The new psychiatric hospital in Vejle, in the Region of Southern Denmark, is designed to support the Region's focus on outpatient services. The healing architecture concept stimulates patients' recovery and well-being, effects that are also enjoyed by staff.

Protected by a forested hillside, the hospital's individual units merge with the landscape at perpendicular angles, allowing a maximum of greenery.

The architectural principles underlying the hospital's design have led to an optimal environment for patients' healing and re-

covery — for instance, by ensuring ample light throughout the building, easy access to green outdoor spaces and transparent wards with easy overviews.

To utilize the healing effect of light, the design provides ample natural and artificial light, with glass panels and interior courtyards allowing daylight to flood the buildings. The withdrawn ceilings and interior glass surfaces help the light extend even further through the building. The wards furthermore offer 24-hour colored light therapy to support patients' natural circadian rhythm. The result is better sleep, leading to faster recovery. Staff likewise benefit from these features.

The design encourages physical activity while reducing the need for coercive measures. Since its opening, the hospital has registered a 50% decrease in physical restraint measures, and has been widely acknowledged for its healing architecture.

The psychiatric hospital was inaugurated in 2017 as the first healthcare project in Denmark to be built as part of a Public—Private Partnership (PPP). The hospital is operated by the Region of Southern Denmark, designed by Arkitema Architects and financed jointly by Sampension, PensionDanmark, MTH, DEAS and MOE as investors, owners, builders and maintenance providers.



A next-generation patient-centered hospital

● Showcasing cutting-edge design in healing architecture, Aarhus University Hospital represents the next generation in patient-centered care.

Designed by C.F. Møller Architects in collaboration with Cubo Architects, this leading hospital in the Central Denmark Region stands as testimony to the systematic application of evidence-based knowledge of healing architecture. This approach has influenced every decision in the hospital's physical design, from the exclusive use of single-bed rooms, to ensuring daylight everywhere, to intuitive wayfinding favored by a city-like layout.

The design of the exterior was guided by an ambition to achieve flexibility and future-proofed functionalities while allowing the extensive gardens and landscapes to provide opportunities for relaxation and tranquility.

By keeping its users in focus, Aarhus University Hospital has successfully promoted the involvement of the patients' families and ensured optimum working conditions and streamlined workflows for all employees.

Facts

- Completed in 2019, it is Denmark's largest healthcare construction, which merges the two former university hospitals of Aarhus Hospital and Skejby Hospital. Aarhus Hospital was itself a merger from the four individual hospitals of Aarhus Municipal Hospital, Aarhus County Hospital, Marselisborg Hospital and Samsø Hospital in 2007.
- 216,000 m² new build and 159,000 m² conversion = 375,000 m², total area: approx. 970,000 m²
- 797 beds, 43 dialysis stations and 80 hotel beds for patients and their families
- Received the 2017 Building Better Healthcare Award as "Best International Design"

The North Wing: Healing architecture for the future

The North Wing is the latest extension to Rigshospitalet, the leading hospital in the Capital Region. Informed by the ambition to improve patient well-being and healing, the building's design accommodates healthcare professionals' expectations for the hospital of the future.

As a step towards a more modern Rigshospital, the new building for outpatient treatment will provide the framework to ensure continued delivery of high-quality care and

treatment and thus support the hospital's new role in the future healthcare system.

The new extension's 54,000 square meter features more than 200 single rooms, operating rooms, outpatient clinics and an intensive care unit. The unusual zig-zag building design was inspired by the image of a cardiogram intersected by a main "artery" route. While the zig-zag structure invites patients to take a leisurely stroll or a rest in a secluded zone, the straight artery route allows staff to navigate quickly from one end of the building to another. Patients' rooms offer recovery in comfort away from the busy hospital environment.

Throughout, the design of the North Wing has been guided by the concept of healing architecture. Large glass sections allow the day-

light to flood the building, connecting the building's interior with the greenery outside to create a therapeutic and calming effect that stimulates recovery.

Two spiral staircases and four central elevator towers connect the floors with the central common area. The daylight atrium gives access to the staircases.

The artwork exhibited in the atrium brings color and life to the building, while softening the sterile hospital environment. The works can also be enjoyed from outside of the hospital. The result is a hospital building that welcomes its visitors, while providing patients with optimal conditions for well-being and recovery.

The design and layout of the North Wing are the result of close collaboration between two architectural firms, LINK arkitektur and 3XN Architects.





Involving users and VR in designing a new children's hospital

BoerneRiget, the new children's hospital in Copenhagen, has implemented a unique approach to treating children, aiming to reduce stress in children and improve compliance and outcomes. This involves using technology such as VR sessions to support implementation of the new approach.

Located alongside Rigshospitalet, the leading hospital in the Capital Region, BoerneRiget will offer treatment to children, adolescents and pregnant women. The structure's futuristic shape resembles two children's hands with fingers reaching for the light, the city and the greenery. A healing environment is provided by the high-quality air, ample daylight and lush winter gardens. Children and their families will find rich opportunities for play and creativity there.

To foster communication and mutual understanding between project advisers, healthcare staff and patients, the development process included user sessions in a computer-automated virtual environment provided by the software consultancy BIM Equity. In the course of a single week, the new 58,000

m² building was tested in virtual reality by 200 hospital employees. The innovative VR environment enabled them to roam the building interior and interact with 1:1-scale

"It makes a huge difference when they can experience the building in a more intuitive way, which lets them understand and participate in the process of development of the building they are to move into."

3D models. The joint experience offered by this technology sets it apart from other VR solutions.

Moving around in the 3D model as a team, users can virtually understand, develop and test the project from a shared point of view. VR thus translates plans into something much more intuitive and easily grasped for the layperson and for healthcare staff.

"Doctors, nurses and midwives may have difficulties understanding design drawings or plans. It makes a huge difference when they can experience the building in a more intuitive way, which lets them understand and participate in the process of development of the building they are to move into." - Toke Laugesen, Architect, BoerneRiget.

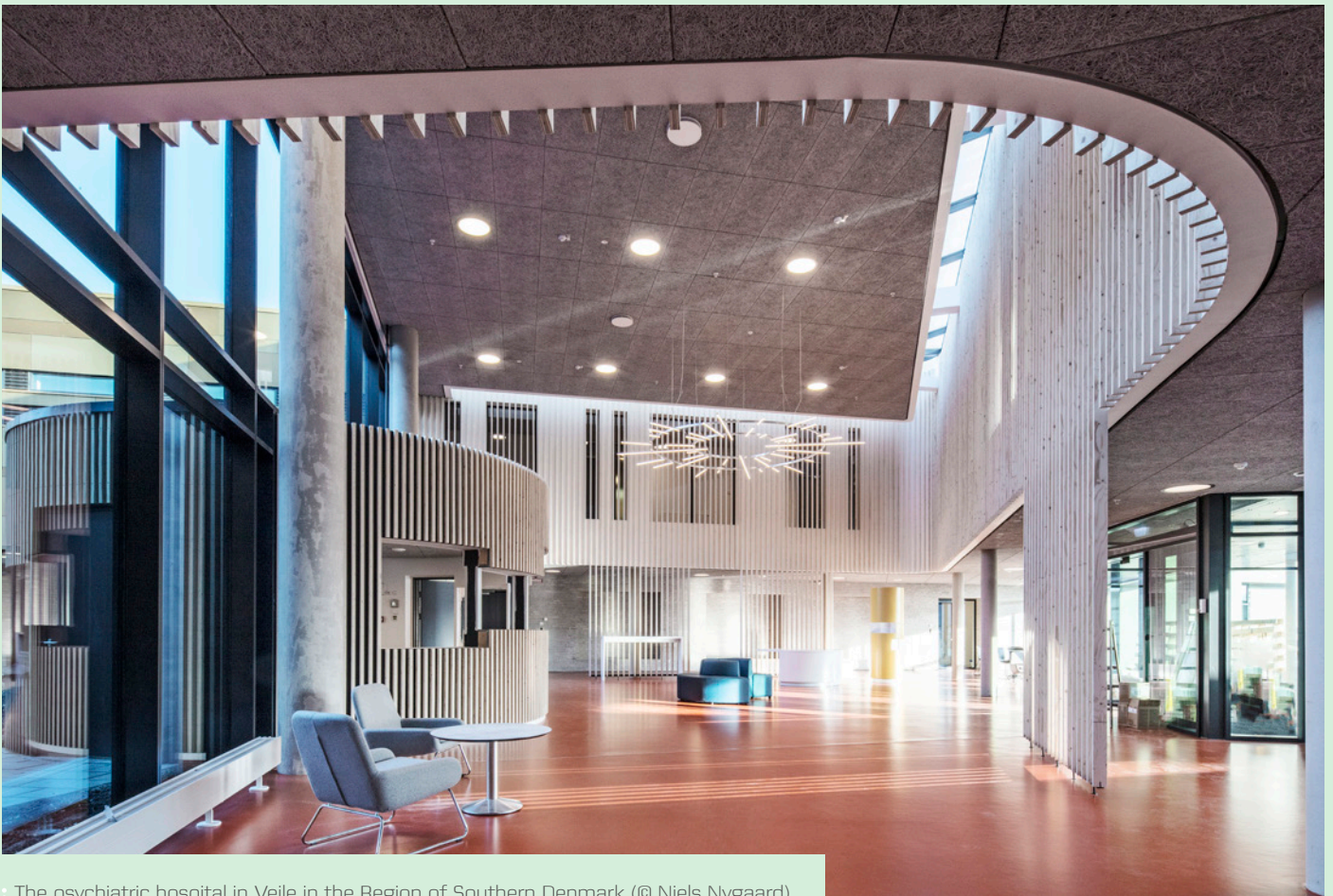
BoerneRiget is designed by 3XN in collaboration with Arkitema Architects, NIRAS, Kristine Jensen Architects and Rosan Bosch Studio.

Facts

- 58,000 m²
- 15 operating rooms
- 57 outpatient clinics for children and adolescents
- 30 outpatient clinics for adults
- 14 delivery rooms
- Expected opening in 2025



: The North Wing at Rigshospitalet in the Capital Region of Denmark (© Adam Mørk)



: The psychiatric hospital in Vejle in the Region of Southern Denmark (© Niels Nygaard)



High performance hospitals with innovative logistics solutions

With the new hospital landscape in Denmark, our hospitals will be playing highly specialized roles. At the same time, the healthcare system is under pressure to meet patients' expectations of efficient and high-quality treatment. Therefore, innovative just-in-time logistics solutions are necessary to optimize patient flows and to reduce patients' length of stay.

Denmark's focus on hospital logistics has been instrumental in achieving a significant increase in productivity. New processes and technology have enabled just-in-time delivery of services and equipment, while ensuring coordination between all specialties and thousands of patients and staff. Our solutions encompass supply logistics, clinical logistics, sterile goods and sample logistics.

Danish hospitals continue to focus on organizational and technological development,

including innovative logistics solutions to optimize efficiency and reduce patients' length of stay. To optimize patient flows in the new hospitals, the next step will bring new logistics solutions using previously unavailable data for novel technologies, such as robots and artificial intelligence (AI).

Mobile robots have already been implemented in some of Denmark's university hospitals and in other large hospitals to handle logistics tasks, thus easing staff workloads and freeing up time for patient care. Self-driving autonomous mobile robots (AMRs) take care of delivering laundry, transporting blood samples to labs and bringing medicines to wards. Combining robotic technology and artificial intelligence is part of the next step, as artificial intelligence goes hand in hand with logistics and planning. *The right patient in the right bed, at the right time, given the right treatment* – this is the essence of the Danish healthcare system, which AI

solutions will help to enable. New robotic solutions controlled by software and sensor technology will facilitate the use of applications for a wide range of tasks at different locations in the hospital – even among patients on the wards.

Freeing up time for the core tasks of hospital departments through the use of artificial intelligence for planning and optimization will ensure better hospital services that will benefit both patients and staff.

Facts

A previous Healthcare DENMARK white paper was dedicated to a detailed description of the Danish concept of hospital logistics.



Optimizing capacity management with intelligent hospital planning

- An innovative patient flow system gives clinicians a real-time overview of patients and beds in all hospitals in North Denmark Region.

Difficulties tend to arise with reductions in the number of hospital beds, and it can be a challenge to ensure the correct placing of incoming acute patients. Furthermore, when patients are transferred from one ward to another, data loss and prolonged hospitalization are not uncommon occurrences.

The Columna Patient Flow software suite is the result of an innovative project involving clinicians from seven hospitals — headed by Aalborg University Hospital, Aarhus University and the Danish software company Systematic. This innovative solution supports the planning and capacity process in hospitals, and enables clinicians, coordinators and administrators to see how the capacity is related to the number of patients admitted and expected discharges on each

ward and in all departments, across the entire region. With an overview of the region's total capacity, users can coordinate actions for patient flows in hospitals, within clinical specialties, and even between hospitals, if necessary. This can take place via

“The system is easily accessible and can be adjusted continuously with entries in real time. We also experience enhanced cooperation and greater understanding across hospital wards.”

ten-minute capacity meetings in the morning through video conference calls, while in the afternoon, coordination is conducted via the system.

“The system is easily accessible and can be adjusted continuously with entries in real

time. We also experience enhanced cooperation and greater understanding across hospital wards.” - Karin Hedegaard, Head of IT, Aalborg University Hospital.

The solution currently offers occupancy level forecasts for seven days ahead, based on machine learning. The next step is to include forecasts on each patient on the basis of their clinical data and on patients to be admitted.

This will help optimize patient flows during admittance, as the system can predict both length of stay and readmission risk.

Facts

- Optimizes capacity utilization through improved planning
- Gives an overview of bottlenecks in the patient flow
- Enables a broader view of patient progress, combined with forecasts

Aalborg University Hospital improves sample quality with an intelligent sortation solution

● Data-driven decisions, full traceability and temperature monitoring have significantly increased the quality of blood sampling and workflows at North Denmark Region's university hospital while retaining high patient safety. Higher patient safety and reduced redraw of blood samples proves a solid business case.

By implementing an intelligent sample traceability, monitoring and sortation solution, Aalborg University Hospital has managed to reduce the number of temperature deviations registered from 100% of the samples

received when the hospital started to use the solution to less than 4% today.

In the fully automated solution, blood samples are handled, unpacked and sorted, while traceability and monitoring of temperature conditions is ensured from the time the sample is collected at the general practitioner's until it is ready for analysis at the laboratory.

As such, this solution allows for automated and data-driven quality control of sample materials, which reduces the number of errors in pre-analytics and increases the quality

of test material, as well as patient safety. Ensuring correct sample temperature also helps to prevent the need for redraw of blood samples.

"We can now verify that the high quality we believed we had did not actually exist. We thought our test material remained constant at 21 ± 1 degrees Celsius, but that was not the case. So now we have full traceability and the true monitoring of our test material. This quality boost is invaluable." - Annebirthe Bo Hansen, Ph.D., Head of Clinical Biochemical Department, Aalborg University Hospital.

The automated monitoring system has also helped improve workflows, while at the same time significantly improving the working environment at the laboratory through the automation of unpacking. The procedure also prevents repetitive strain injuries from arising.

The innovative solution has been developed by the Danish company Intelligent Systems, in close collaboration with Aalborg University Hospital and the robotics company LT Automation.

"We can now verify that the high quality we believed we had did not actually exist. We thought our test material remained constant at 21 ± 1 degrees Celsius, but that was not the case. So now we have full traceability and the true monitoring of our test material. This quality boost is invaluable."





Artificial intelligence improves hospital robot traffic

Autonomous robots that run anywhere and independently of floor installations are increasingly being implemented in Danish hospitals. At the Hospital of Southern Jutland, an autonomous mobile robot with AI features improves robotic traffic and ensures internal logistics run as planned.

An MiR100 robot from Mobile Industrial Robots, based in Odense Municipality, wends its way among trash cans, trolleys, scooters, porters pushing beds, groups of workers and other logistics robots. Having delivered its load of food, it returns the dishes to the kitchen four times a day in the Region of Southern Denmark's Aabenraa hospital.

The robot's AI feature avoids the problems of robots meeting in narrow doorways, blocking traffic by waiting for each other. AI cameras placed above doors are able to distinguish between robots and other obstacles, such as people or other moving objects. If these ob-

jects enter a narrow passage, the MiR robot will park on the side, waiting until the way is clear. However, if a single person enters the doorway, the robot will continue, as it knows there is room for both of them. The AI cameras thereby improve robot traffic, ensuring

"I expect to see many more robots in hospitals, both collaborative and fully automated, to pull, lift and push what's needed."

the smooth and efficient execution of the hospital's logistics.

Automated internal transport provides benefits to both management and employees. Whereas previously, kitchen staff had to walk to hospital departments to pick up the used service, a click on a tablet is now enough for the robot to start collecting the dishes.

"Robot technology will free up time for patient care and improve the working environment. Porters' jobs involve postures that strain their shoulders and legs, and repetitive movements are also a problem. I expect to see many more robots in hospitals, both collaborative and fully automated, to pull, lift and push what's needed." - Tom Johansen, Porter Manager, Hospital of Southern Jutland.

Facts

Odense Municipality, in the Region of Southern Denmark, is home to one of the world's most successful robotics and automation industries. A strong national robotics cluster, which includes more than 130 companies, focuses on internationalization and provides an extensive network of global partners.

Robots disinfect hospital with ultraviolet light

● Twelve minutes are all a robot needs to automatically disinfect all surfaces in a room with ultraviolet light. At Odense University Hospital in the Region of Southern Denmark, the innovative robotics solution enables cost efficient cleaning and reduces risk of infection for patients and staff.

Two UV disinfection robots from the Danish company UVD Robots in Odense Municipality are used in the Department of Hematology, which is visited by some 29,000 outpatients and inpatients over a year. In sixty patient rooms, toilets, and bathrooms, these robots supplement the normal cleaning procedure.

The UV disinfection robots combine innovative mobile robotics technology with a UV-C light module. With robots a part of the cleaning cycle, bacterial counts are greatly reduced before a new patient enters the ward. This helps prevent the spread of bacteria and other harmful microorganisms, reducing hospital-acquired infections, which affect 50,000 patients in Denmark each year.

Having cleaned a room, the hospital staff ensures that the furniture is optimally placed for UV-C light illumination of surfaces. Using a tablet device, the staff then instructs the robot to leave its docking station, locate and enter the room. The staff checks the robot on arrival in the room to ensure that

everything is ready, and then start the robot. Twelve minutes later, the disinfection process is completed.

Rather than idling in the Department of Hematology, the robots are also put to work on disinfecting other areas of the hospital. At the beginning of 2021, after twelve months trialing this procedure, the Department of Clinical Microbiology will evaluate the impact of the UV disinfection robots on the number of hospital-acquired infections.

Recent testing in Taiwan has shown that such robots, if used properly, result in bacteria counts being reduced by 77% in intensive care units and 83% in operating rooms.





Automation of cleaning processes improves hygiene and ergonomics

At Viborg Regional Hospital in Central Denmark Region, hygiene and ergonomics have gotten a boost with an automated cleaning machine that provides much faster and safer cleaning of beds.

Manual cleaning of beds is a hassle – it takes lots of time, reaching all the edges and corners is awkward, and the work environment is poor. But automating the process can help overcome those challenges.

Viborg Regional Hospital obtained special funds for a new automated bed and mattress washing machine, which was installed in 2017, with a capacity to clean up to 25 beds per hour. On a daily basis, the hospital uses the machine to clean about fifty beds, mattresses and pillows, besides wheelchairs and other assistive aids. The new hygienic processes have improved patient

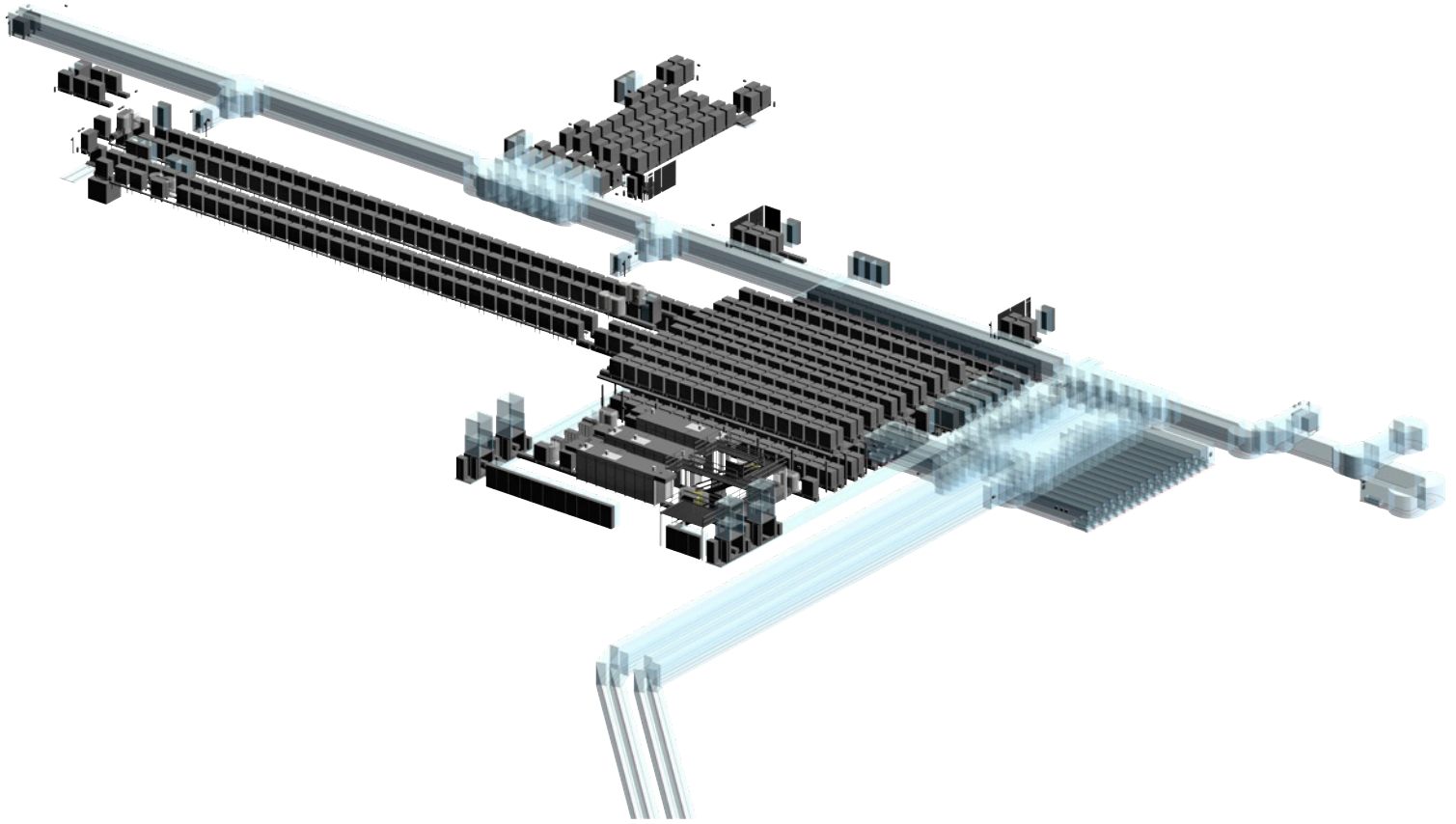
safety; further benefits include significant time savings and better ergonomics for hospital staff.

“Our new washing machine from Semi Staal has had a huge impact on both hygiene and efficiency. It only takes a few minutes from when a bed enters the machine until it comes out, spick and span, ready for use. And bacterial tests show extremely good results.” - Hanne Louring, Service Consultant, Viborg Regional Hospital.

The washing, disinfection, and drying processes take place in a tunnel, so that contamination of the cleaned output is avoided by separating the reception bay for unclean materials from the clean area. Depending on the materials to be cleaned, the machine operates with different programs: mattresses and pillows are cleaned by steam and ultrasound, while hot water and disin-

“Our new washing machine from Semi Staal has had a huge impact on both hygiene and efficiency. It only takes a few minutes from when a bed enters the machine until it comes out, spick and span, ready for use. And bacterial tests show extremely good results.”

fectants are used for bed frames, aids, and plastic crates. With these processes, good bacterial results of little as 2.5 CFU/cm² are achieved.



• The hospital's logistical heart is a fully automated buffer station with a capacity of 530 goods carts, serviceable from two sides by four multilevel cranes.

Automated service village improves hospital logistics

When the New Aalborg University Hospital in North Denmark Region opens in 2022, its highly automated 20,000 m² service village will ensure an efficient and energy saving hospital operation for itself and other hospitals in the region by optimizing flows and processes.

Achieving a simple and effective logistics setup was a driving factor in planning the new hospital: a key principle was a setup that would allow hospital staff to focus on patient care and other primary tasks, rather than worrying about logistics. Partnering with the consultants Rambøll Hospital Logistics for the construction project, the starting point was to focus on processes, hygiene, physical framework and interfaces between automation and people.

Rather than having central facilities for warehousing, catering, sterilization, storage and

waste disposal, the hospital's logistical heart will be a fully automated buffer station with a capacity of 530 goods carts, serviceable

“Planning principles that enable automation and effective hospital logistics are important in all new hospital building projects. Pneumatic tube systems and AGVs form part of the new technologies that enable more effective processes in the new hospital.”

from two sides by four multilevel cranes and connected with an automated guided vehicle system (AGV) servicing about 40 rooms.

Three fully automated multichamber washing lines for disinfection, manual pick-up locations at the waste yard and truck bays, a 40-cart interlocked sterile buffer and a 60-cart buffer for warehouse goods will also form parts of the system.

The project features a very high level of automation, optimized flows and processes, as well as flexibility and opportunity for future expansion. The latest state-of-the-art technology has been integrated to meet the need for a unique solution.

“Planning principles that enable automation and effective hospital logistics are important in all new hospital building projects. Pneumatic tube systems and AGVs form part of the new technologies that enable more effective processes in the new hospital.” - Heine Overby, Office Manager for Logistics, New Aalborg University Hospital.



• Hvidovre Hospital with solar panels on roofs.

Sustainable hospitals and environmental challenges

● All over the world, countries are introducing goals to reduce their energy consumption. In Denmark, hospitals are required to contribute to the green agenda, and therefore new hospital projects are launching eco-friendly initiatives and environmentally friendly practices to the design, building and management of facilities, in order to reduce their carbon footprint and improve patient care.

Making future hospitals sustainable requires solutions that are efficient and resource-economical. With investment in 16 new hospital projects, the opportunities for green procurement in cooperation with private stakeholders are already being exploited. One such project is found at Aalborg University Hospital in North Denmark Region, which has partnered with the private company Aalborg Portland to use the water left over from their concrete production in the hospital's cooling system. The new facilities ensure the environmentally and financially sustainable future operation of the hospital.

With hospitals typically using significantly more resources, and producing more waste than commercial buildings of comparable size, it is critical that resource management is improved through effective environmental strategies. To meet the challenge of reducing CO₂ emissions and achieving positive long-term effects on operational costs, the design and construction of new hospital buildings must be considered. While the construction of Denmark's new hospitals must be made sustainable, renovation and retrofitting will ensure decarbonization of our existing hospital buildings. This includes the use of renewable energy sources, such as solar panels and innovative cooling solutions. As an example, Hvidovre Hospital in the Capital Region of Denmark has installed solar panels on the roofs, supplying CO₂-free electricity to the hospital.

Efficient water and energy usage

Using energy and water efficiently is vital in reducing CO₂ footprints. The introduction of new solutions, processes and designs lowers environmental impact and operational costs through increased efficiency and decreased

energy and water costs. Major energy reductions can be achieved by means of innovative solutions, such as efficient pumping systems, district heating and cooling, natural ventilation and lighting, integrated solar panels and smart building technologies.

Circular resource use

Circular approaches to the use of resources are key to achieving sustainable hospital operation. By reducing, reusing and recycling the waste produced in hospitals, we can not only stabilize operational costs, but also reduce the environmental footprint. Studying various cases of waste handling in hospitals has shown that waste need not be discarded, but can actually become a valuable resource that enables clean energy generation. This requires, however, behavioral changes so that hospital staff are encouraged to contribute their knowledge toward reduced consumption, more sustainable solutions, and so on. Adjusting usage and workflows to ensure both the continuity and development of high quality patient care can only come about when everyone is committed to the goal.

District cooling of New Aalborg University Hospital

In a collaboration with the city utility company, Aalborg Forsyning, the New Aalborg University Hospital will be cooled by water from a nearby lake. This system, which is the first of its kind in Denmark, will contribute to a substantial reduction in annual CO2 emissions.

In the first system of its kind in Denmark, cooling will be provided for the North Denmark Region's 170,000 m² university hospital using water from a 30-meter deep chalk pit, located some 3.5 km north of the new hospital in the Aalborg Portland facility.

In principle, district cooling is a reversal of the district heating process, with cold rather than hot water being supplied. From the lake, water at 8–12 degrees Celsius will be piped to the hospital, where it will cool patient rooms, staff and clinical facilities and medical equipment.

Only the pumps will generate CO₂ here, and the annual carbon dioxide savings to the new university hospital will be 500–700 tons. This supports North Denmark Region's ambitious "Climate Region" measures to reduce emissions, thereby contributing to achieving Denmark's climate goals. Other sustainable initiatives taken by the Region include the in-

roduction of biogas-powered buses, reductions in resource consumption and waste volumes and intensified recycling measures.

Facts

- Local public-private collaboration between the North Denmark Region, Aalborg Forsyning and Aalborg Portland
- Contract value of approximately EUR 36.2 million, with a maturity of twenty years





Solar cell park at New Odense University Hospital

The Region of Southern Denmark is currently building its largest hospital, which will cover 296,000 m². Solar panels and other sustainable initiatives were key elements of the design phase to supply CO₂-free electricity to both the construction site and hospital operation.

“This is a frontrunner project. No other hospital in the country has similar capacity: in fact, the total electricity production from all other hospitals in the region is about one sixth of the future capacity at New Odense University Hospital.”

Solar energy is an obvious candidate for sustainable measures in the construction of Denmark’s future hospitals. The New Odense University Hospital in southern Denmark will be powered by a large solar power plant close to the hospital. Already supplying power to the building site, the plant’s capacity will have surplus capacity for other buildings when completed in 2022.

The output of the solar power plant will be equivalent to the electricity consumption of 1,100 households, more than enough to meet the needs of the large university hospital.

“This is a frontrunner project. No other hospital in the country has similar capacity: in fact, the total electricity production from all other hospitals in the region is about one sixth of the future capacity at New Odense University Hospital.” - Torben Hedegaard

Jensen, Project Director, New Odense University Hospital.

The solar power plant is being supplied by the company Better Energy Solutions.

Facts

- Air quality will benefit from the large energy savings
- The plant will provide over 45% of the hospital’s summer power consumption (yearly average 20%)
- 35% of construction site’s electricity consumption will be covered
- There will be an estimated greenhouse gas reduction of 1.3 tons per year
- The panels generate 4,650,780 kWh annually

Plastic recycling at hospital provides both environmental and economic benefits

Central Denmark Region's efforts toward circular economy show that reducing plastic waste has by far the greatest effect, both economically and environmentally. By changing procedures at the region's hospital laundry, a significant reduction in plastic consumption is achieved.

An analysis conducted at Aarhus University Hospital in November 2016 indicates that only about 37% of the sorted plastic is technically recyclable. Even if it were possible to locate market players to recycle this plastic waste, CO2 emissions would be reduced by only 1.2 tons and the cost by EUR 13,285 compared to waste incineration.

It is much more attractive to lower the total amount of waste by 20%, which would achieve a 1.5 ton reduction in CO2 emissions, with almost ten-fold savings of more than EUR 134,200. The decision to focus on waste reduction was thus a foregone conclusion in the hospital's work on sustainable solutions for the future.

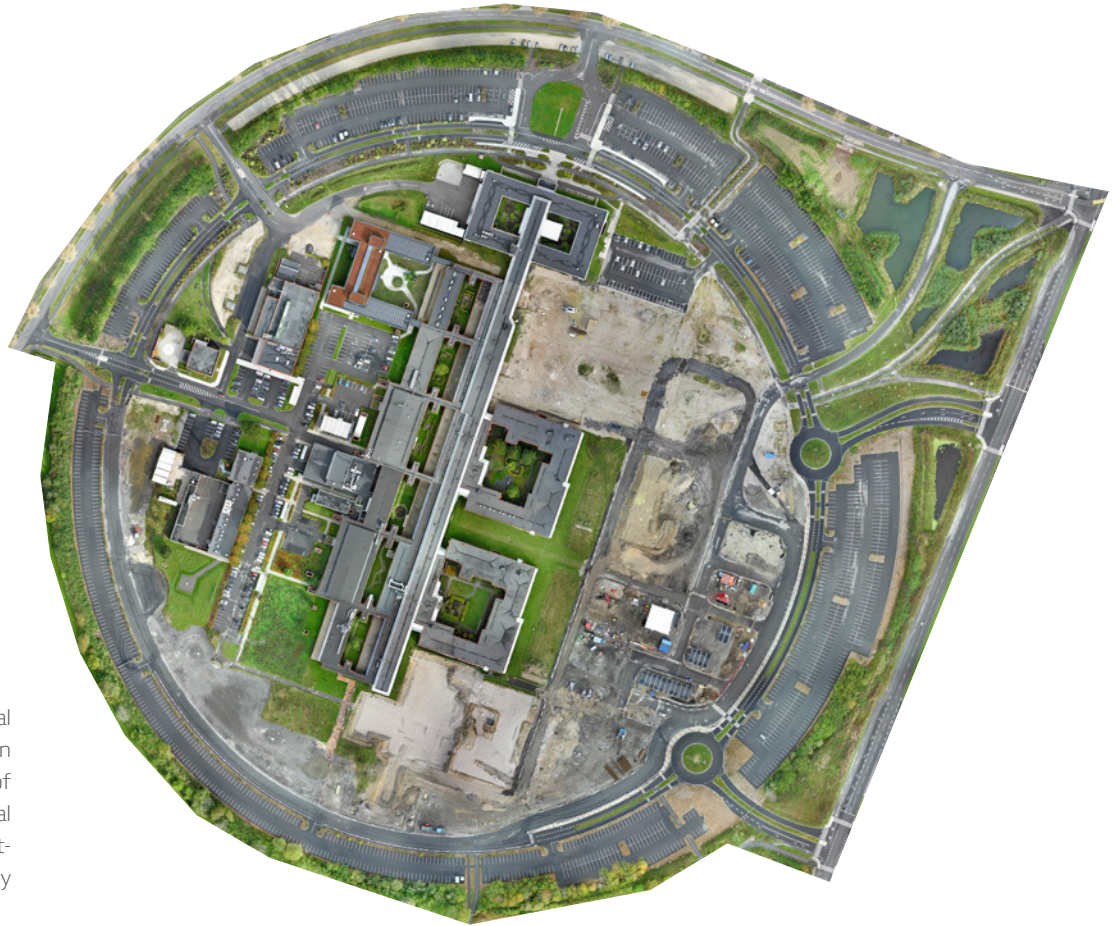
The region's own Nordic Swan eco-labeled hospital laundry, MidtVask, has thus changed its procedures. One example is the plastic covers used on linen carts during transport. Reducing their thickness from 35 microns to 25 microns has saved 4.5 tons of plastic and reduced costs by 10%–12%. The greater roll capacity saves time spent on

changing the cover and the easier handling of the slightly thinner bags has also saved time by being quicker to pull over the carts.

In addition to the reduced plastic consumption, the laundry now avoids mixing plastics materials of different colors, in order to improve the sorting of used materials. This means that, rather than paying for the collection of used covers, the plastic can now be recycled.

Overall, the reduction in plastic consumption and the increase in recycling have saved 26–34 tons of CO2 equivalents.





Zealand University Hospital Køge in September 2019 seen from above. Forming part of the future University Hospital Køge, the majority of the existing buildings will be covered by the ESCO project

Energy services project improves energy efficiency at new university hospital

Sustainability will be a premium feature in the construction of University Hospital Køge in Region Zealand. To provide energy savings, an Energy Service Companies (ESCO) project has been established to ensure operating and energy optimization of the existing buildings.

Region Zealand has long focused on sustainability and energy savings. All construction projects exceeding EUR 13.4 million must be certified by the German Green Building Council (DGNB), while smaller-scale projects are energy screened according to regional guidelines.

The region has concurrently worked on energy optimization of the existing building stock with many years of service ahead. Most recently, an ESCO process was initiated which, following intense analysis, has led to agree-

ments in 2019 on the implementation of a number of energy-saving projects. This gives the region a comprehensive overview of the potential for savings based on uniform assessment criteria.

At the same time, it is an opportunity to pool many small projects in a large tender. This helps us optimize projects with short-term effects with projects that provide substantial long-term benefits.

After Region Zealand called for tenders for seven hospitals, contracts for approximately EUR 26.8 million were signed, with an expected payback period of 15–20 years. Of this amount, some EUR 5.2 million cover projects at University Hospital Køge.

The thirteen projects at the future University Hospital Køge concern only those parts of the existing buildings that will be inte-

grated in the new hospital. They include replacement of lighting fixtures, renovation of ventilation and control systems, installation of one-handle mixers on utility water, and installation of solar panels. The Køge ESCO project is expected to provide savings of 1.2 GWh in electricity, 0.5 GWh in heating, and 2,900 m³ of water.

"The ESCO project will optimize our hospital's operating and energy expenditure. Financing the project through energy savings has opened up new possibilities." - Mads K. Kristoffersen, Technical Manager, University Hospital Køge.

The first projects went ahead in January 2020, with completion expected by the end of 2021.



State-of-the-art wastewater treatment plant at Herlev Hospital

In the Capital Region, the purification and reuse of wastewater in the new sustainable wastewater treatment plant at Herlev Hospital represents a double gain for the environment and the hospital's finances.

The mixture of water and pharmaceutical agents, pathogens and antibiotic-resistant bacteria carried by hospital wastewater cannot be treated by conventional means. To meet this challenge, Herlev Hospital in the Copenhagen area began directing all wastewater through a brand new treatment plant in the summer of 2014.

The world's largest and most modern of its kind, the plant was established as part of a public-private collaboration between the Capital Region, Herlev Hospital, Grundfos Biobooster and others.

New sustainable methods have been developed to extract medicine residues, endocrine disruptors and antibiotic-resistant bacteria from the sludge. The cleaned water is so pure that it can be sent directly back to nature, saving the cost of treatment at a central plant.

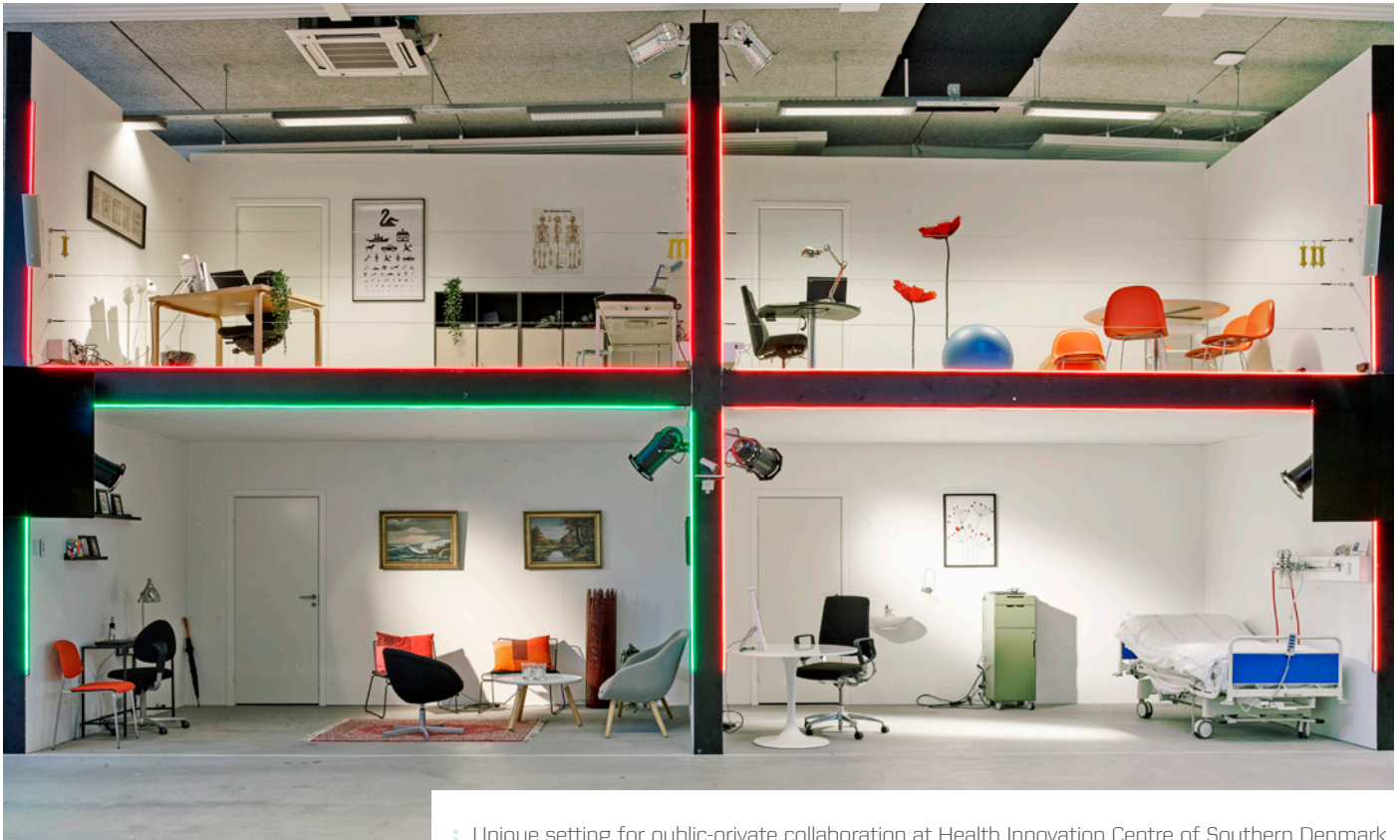
The hospital plant has a daily capacity of 600 m³, corresponding to the amount of wastewater discharged by 3,000 people. To ensure a high standard of water quality, a variety of biological purification processes and membrane filtration are used, followed by activated carbon and ozone polishing.

The plant also cleans the air emitted during the cleaning process, removing both odors and harmful pathogens in its closed and noiseless system.

A report based on 18 months of operation has shown a 99.9% reduction in drug substance loads, making the water pure enough for reuse in the hospital's cooling system.

Facts

Apart from the Capital Region, Herlev Hospital, Grundfos Biobooster, the collaboration behind the plant included the companies DHI, Ultraaqua and Neutralox. Support was obtained from the Danish Business Authority's Market Development Fund and others.



• Unique setting for public-private collaboration at Health Innovation Centre of Southern Denmark.

User-driven design and innovation

● Basing innovation and ideas for new solutions on strong collaboration between hospitals, universities and private companies has earned Denmark international recognition for its user-driven innovation culture. Public-private partnerships with high levels of stakeholder involvement are defined by a uniquely Danish concept which is playing a key role in the new hospital construction projects.

In Denmark, we cherish our proud tradition of cooperation between the public and private sectors — in particular in the healthcare sector. The many new hospital construction projects provide unique opportunities for entering into various forms of public-private partnership. Not only does this apply to the actual construction process — partnership also characterizes the development of the innovative solutions to be used when the hospitals begin operations.

The new hospital landscape — involving the reorganization of hospitals and increasing the individualization of treatment — requires

safe and innovative solutions developed as part of collaborations between end-users and companies known as user-driven innovation projects. This concept plays a key role in achieving successful outcomes for the benefit of patients, the healthcare system and society as a whole.

User-driven innovation projects typically originate with a hospital, a municipal authority, a primary care organization, or another healthcare organization that has identified a problem to be solved through innovative concepts and solutions. In many cases, universities or cluster organizations also play a role in motivating healthcare organizations to bring strategic or daily operation problems forward.

User-driven innovation leads to successful implementation

A high level of user involvement is required to ensure that our current and future needs are identified, so that the proposed solutions will work in practice. Users may include patients, families, healthcare professionals and hospital staff, as their varied perspectives

and experiences are essential in the development of new innovative solutions.

The Danish experience with involving users at a very early stage of the design and development processes helps to ensure the successful implementation and use of the solutions in the new hospitals. Pilot testing of future operating rooms at Odense University Hospital in the Region of Southern Denmark provides an example of a successful user-driven innovation project. In cooperation with the Health Innovation Center of Southern Denmark, patients, relatives and healthcare professionals from across departments, academia and management contributed their insights to the construction of the new operating rooms. Thanks to a full-scale mockup of an operating room, users could participate in simulation tests to uncover issues in a realistic set-up. Clinical staff were thus able to test specific operating scenarios within all medical specialties before implementation, leading to the introduction of new concepts and designs for improved patient safety.

Promoting collaboration and innovation through physical integration

The New Aalborg University Hospital in North Denmark Region is being erected next to the premises of Aalborg University's Faculty of Medicine. The physical integration of the two organizations will strengthen their already well-established knowledge exchange and collaboration on innovation.

Aalborg University Hospital and the Faculty of Medicine at Aalborg University (AAU) have a shared vision of providing healthcare-related education, research and innovation. Their focus on innovation and close collaboration involves staff and patients in translating ideas into new procedures and products to improve treatment and care.

The hospital and faculty buildings will open their doors in 2022. Their physical integration will enable the sharing of auditoriums, lecture rooms and so on, to create synergy between these two strategic partners. The features of the buildings and their shared areas will ensure easy movement of staff and students from one to the other.

The faculty's broad range of healthcare programs, including healthcare engineering and molecular biology, will be served by the new teaching facilities. The medical students' master's program will be taught entirely in the hospital's facilities to strengthen the already established pathways between faculty and university, ties that have long fos-

tered entrepreneurship among innovative clinicians and students.

The merger of the two organizations will thus lead to new and innovative ways of sharing facilities and staff, helping to better coordinate and utilize resources.



The physical integration and shared areas will ensure easy movement of staff and students from one building to the other.



• Prototype of the new psychiatric bed.

Users design their own psychiatric bed

By involving users in a public-private innovation partnership, a new type of bed has been designed for psychiatric patients' rooms. Both patients and staff have welcomed the initiative and as a result, the new bed increases patients' well-being and improves work environment for staff.

In a successful collaboration between the Region of Southern Denmark and the Capital Region, the new bed was developed for use in psychiatric wards. After a two-year design phase, the so-called Resilience Human Life Carebed was introduced in the Region of Southern Denmark in autumn 2015. It was later introduced to psychiatric wards in the North Denmark Region and the Central Denmark Region, both of which contributed to the design.

The bed is manufactured by the company Agitek, who involved patients and staff in its development from day one. The result

is a cordless, battery-powered, easy-to-clean bed that goes a long way in implementing patients' ideas while ensuring a safe and convenient work environment for the staff.

“During the development process, there was a great focus on both staff and patient perspectives in their interactions with the bed. The result is a completely new type of bed, one designed for and by the users.”

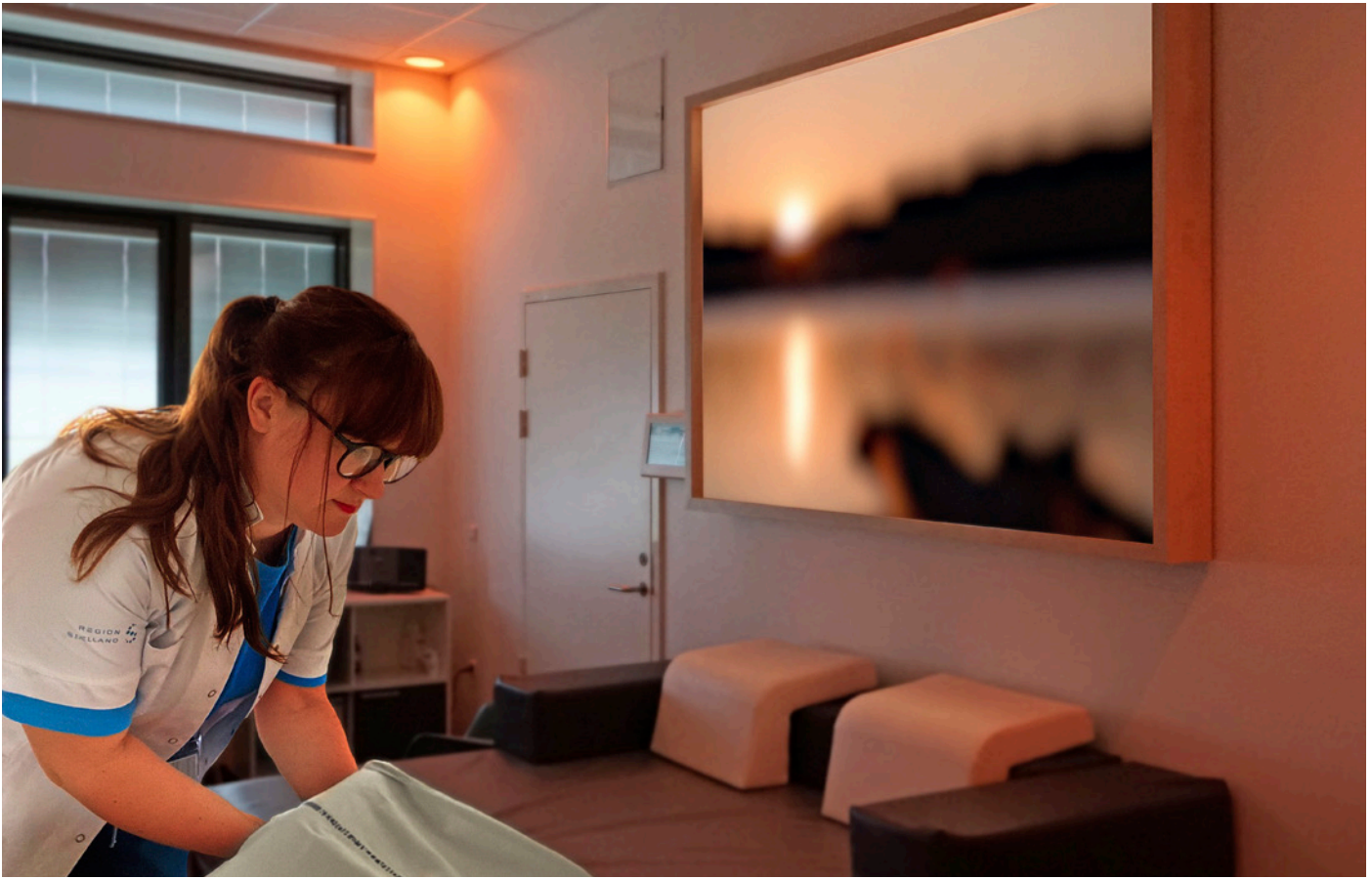
The bed has proven effective in preventing psychiatric patients from self-harming behavior, while the patients say they now sleep better and feel more comfortable during admission.

“The goal was to develop a bed that contributes to the values underlying psychiatric nursing in both design and functionality. During the development process, there was a great focus on both staff and patient perspectives in their interactions with the bed. The result is a completely new type of bed, one designed for and by the users.” - Ole Rytov, Director of Specialist Nursing in Psychiatry, Region of Southern Denmark.

The bed has improved the work environment for staff, as it is designed for use both in normal day-to-day use and in stressful acute situations.

Facts

A multi-functional comfort cushion called SenceCircle, allows the bed to be transformed into a sofa or a “comfort zone”.



Innovative sensory concept at new mother-child department

● A new sensory delivery room concept creates a relaxed and homely atmosphere, with an overall soothing effect on both women giving birth and hospital staff.

With the same key facilities as an ordinary delivery room, the sensory delivery room is furthermore equipped with ambient light and specially designed audiovisual programs with a user-friendly interface. Providing a stress-reducing ambience in the delivery ward and supporting birthing women, the sensory delivery rooms also ensure a better working environment for the midwives during their night watches.

Slagelse Hospital in Region Zealand is the first in Denmark to implement the Danish company Wavecare’s innovative sensory concept in every delivery room to give all birthing women the opportunity to benefit from its positive effects.

“Our focus is on improving patient outcomes and care with patient-centered innovation. We embrace the opportunities offered by new technology and knowledge. It was therefore a given that we would provide sensory delivery rooms for the entire maternity ward at our newly built hospital.” - Niels Georg Reichstein Larsen, Chief Director, Slagelse Hospital.

The concept was developed by a close public-private innovation partnership (PPP) between North Zealand Hospital in the Capital Region of Denmark, Wavecare and Philips. Continuous refinement and optimization has brought the concept from an innovative experimental project to a scalable solution.

Findings from a study of 476 births in ordinary delivery rooms, compared with 313 births in sensory delivery rooms (same period, North Zealand Hospital)*

6.4% were acute cesareans in the sensory delivery rooms
10.7% were acute cesareans in the ordinary delivery rooms

* Published in the international science journal Nature in 2019

Findings from a satisfaction study of women giving birth in sensory delivery rooms

93% of women reported a very positive impact on their total experience

74% of women reported a very positive impact on their experience of pain



Ergonomic hospital lighting improves minimally invasive surgery

Denmark strives to replace in-patient procedures with outpatient treatment. In order to help increase invasive surgery procedures, ergonomic lighting has been installed in Aarhus University Hospital's 100+ operation rooms — a sign of the high priority given to the work environment and patient safety in Central Denmark Region.

The specially calibrated colored lighting has improved work conditions during minimally invasive surgery, benefiting the well-being of both staff and patients.

"We are in operations for many hours, so light and high-quality screen imagery are extremely important. The new light makes me less tired and reduces the strain on my eyes. It makes a huge difference and gives me the energy to cope better. The green and red lights provide for very clear and pleasant contrasts." - Mikkel Seyer-Hansen, Surgeon, Aarhus University Hospital.

A warm and soothing light welcomes patients as they enter the room. During procedures,

"The new light makes me less tired and reduces the strain on my eyes. It makes a huge difference and gives me the energy to cope better. The green and red lights provide for very clear and pleasant contrasts."

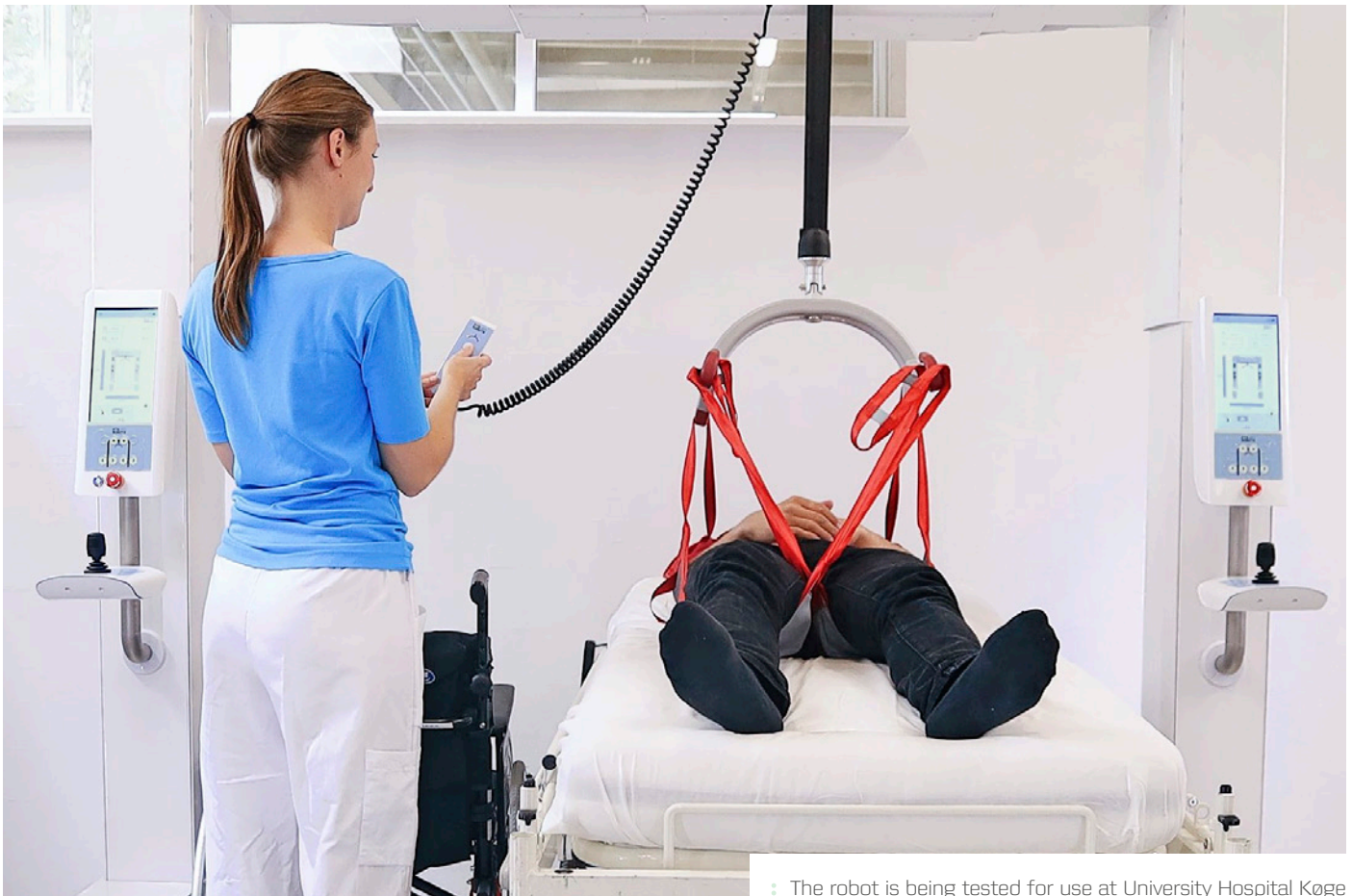
the operation room is divided into different lighting zones that each support specialized work tasks. A combination of green and red light ensures a high image quality, minimizes reflection and relaxes the eyes. During X-raying, the red light enhances the grey-scale image. To reduce glare from the operation lamp during open surgery, the staff can turn

on a customized white light. For cleaning and preparation before the next procedure, a specially developed white light highlights dirt and blood stains and boosts the daylight.

Close collaboration between the staff and lighting experts has ensured customized designs of light settings and user interfaces for each room and speciality. The lighting solution was developed in 2006 by Danish lighting specialist Chromaviso. Today, well over one hundred hospitals across Scandinavia have implemented the solution as a standard.

Facts

Developed by leading surgeons and lighting specialists, the evidence-based Ergonomic Lighting solution is customized for room conditions, workflow and specialist applications.



The robot is being tested for use at University Hospital Køge

Taking patient handling and rehabilitation to the next level

At University Hospital Køge in Region Zealand, a robot developed as part of a public-private innovation project ensures safe and flexible patient transfer, for the benefit of patients and staff.

Conventional patient transfer procedures are burdened by limitations and heavy work expenditure. This led University Hospital Køge to look for robotic solutions for a more flexible patient transfer system.

The innovation project involving the hospital and Blue Ocean Robotics led to the development of the PTR Robot, manufactured by the company PTR Robots, based in Odense Municipality. The R&D process began by mapping all patient transfer situations and interviewing several hundred representatives of relevant caregiver groups. The valuable field and user tests that resulted from the close collaboration between the development team and the healthcare professionals enabled

continuous evaluation, to ensure optimal features in the robot. The simple and intuitive user interface ensures that anyone can use it for safe and flexible patient transfers.

Feedback and input were also sought from broader groups of hospital staff. Close collaboration with hygiene experts, technical staff and IT/communication staff assured definition and early implementation of the requirements and interactions with the robot. This public-private innovation project has enabled the hospital to create better patient transfer options, not only for the patient, but also for the caregiver.

"It's very important for us that our needs are understood and met by our commercial partners. The close and successful partnership with PTR Robots meant that we were listened to in the process of developing the new robot." - Frank Hansen, Chief Project Manager, IT & Equipment, University Hospital Køge.

"It's very important for us that our needs are understood and met by our commercial partners. The close and successful partnership with PTR Robots meant that we were listened to in the process of developing the new robot."

Facts

The PTR Robot has been developed in a local public-private partnership including a diverse group of professionals from Project University Hospital Køge, Blue Ocean Robotics and PTR Robots.

Danish hospital construction for the future

In Denmark, new highly specialized hospitals are being built, taking into account the changing role of hospitals in our future healthcare system. Relying more on outpatient treatment, coherence and primary care, architectural aspects of hospital construction and technological support systems place increasingly high demands on innovation.

The increasing focus on hospitals' relations with patients and the desire to empower and strengthen their independence call for new ways of collaborating with patients, with the primary sector and with hospitals.

This white paper has given an introduction to many of the transformations in the Danish healthcare system, with coherent healthcare offering treatment in new ways, shaped by new demands on hospitals' roles.

Healing architecture is one of the new initiatives in hospital design aimed at helping patients to faster recovery, supported by innovative solutions that optimize the patient flow and shorten patients' length of stay.

Digitalization and automation ensure efficient operation of core services in hospitals, with new work methods, technologies, and organization. This frees up resources for treatment and care, while also providing better health and safety conditions for staff.

This is only the beginning. The role of Danish hospitals will continue to change, with patients expecting ever higher

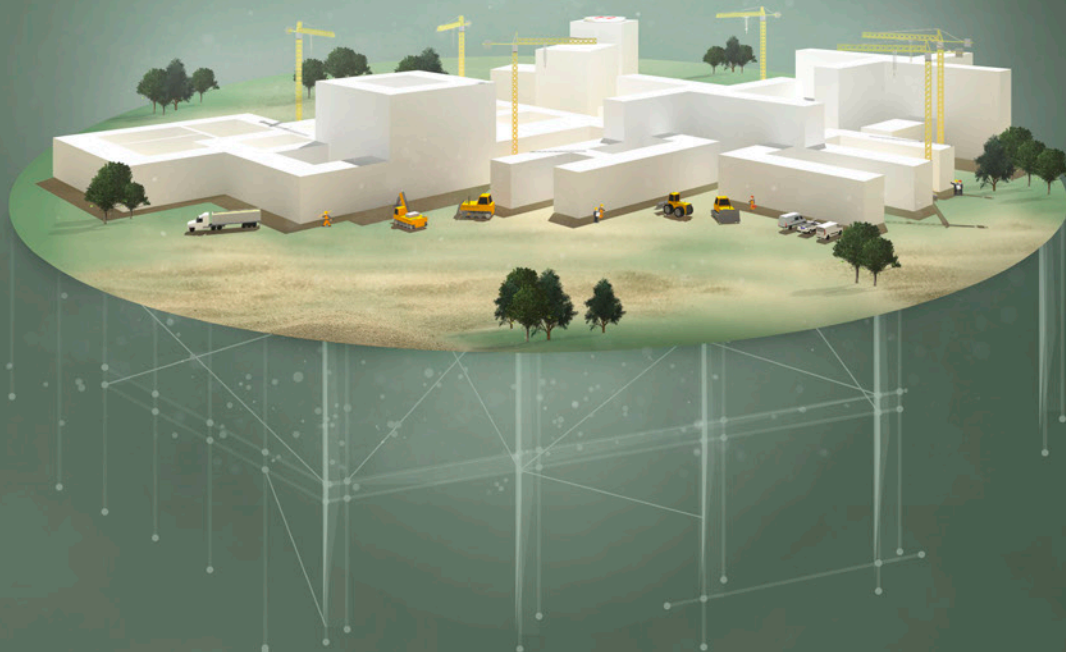
quality treatment and active involvement in their own course of treatment. With longer life expectancy and an increase in the number of patients with chronic diseases, new thinking is required from the healthcare system.

Transformation and changes to our healthcare system will continue at an accelerating pace. Future perspectives include:

- Smartphone and wearable solutions are being developed to support individualized health provision and will become increasingly important in future diagnostics and treatment.
- The national telemedicine solutions being implemented in Denmark will allow patients to take a more independent and participatory role.
- A personalized medicine strategy is being implemented to ensure better and more targeted treatment.

Subsequent white papers will keep you updated on these developments and the impact on our future hospitals. In our previous publications, you can find a comprehensive overview of innovative Danish solutions in relation to current themes in health provision.

To learn more about the new Danish hospital constructions, feel free to contact Healthcare DENMARK. If you want to visit Denmark to study its innovative solutions in detail, you can request a delegation visit through the Healthcare DENMARK website.



About Healthcare DENMARK

Healthcare DENMARK is the international gateway to Danish healthcare expertise and innovation. Our aim as a non-profit public-private partnership is to internationally benchmark Danish best practices within healthcare.

The goal of Healthcare DENMARK is not to sell or promote any specific products or solutions, but to communicate the strongholds of



Hans Erik Henriksen
Chief Executive Officer

Danish healthcare. We do this by attracting health politicians, decision-makers, and journalists to experience Danish healthcare solutions in practice and meet the people behind. Our network is an extensive pool of public sector, private

companies, and other actors in the area of healthcare – all dedicated to providing excellent and efficient healthcare as well as sharing best practices across borders and professions.

“In Denmark our focus on putting the patient first – combined with efforts to improve efficiency and quality – has resulted in a wide array of innovative solutions. I sincerely believe Danish solutions and expertise can have a positive impact on global health.” - Her Royal Highness The Crown Princess of Denmark

If you would like to learn more about our world-renowned healthcare, we can assist you with tailoring a visiting program, setting up meetings, and arranging access to otherwise off-limits areas and people within both the public and private sectors, as well as assist you with local accommodation and transportation.



HRH The Crown Princess of Denmark
patron of Healthcare DENMARK

Healthcare DENMARK has a national and political mandate to provide this service to politicians, relevant top and management level professionals, and journalists working with healthcare.

Backing this public-private initiative is a partner group of both public and private key actors within Danish healthcare, including the Ministry of Health, Ministry of Industry, Business and Financial Affairs, Ministry of Foreign Affairs of Denmark, Danish Regions, Region of Southern Denmark, North Denmark Region, Aalborg Municipality, University of Southern Denmark, Aalborg University, the Confederation of Danish Industry, the Danish Chamber of Commerce, Danish Export Association, Danish Care, Falck, Systematic, Intelligent Systems, Leba Innovation, Mobile Industrial Robots, UVD Robots, OpenTeleHealth, KMD, Lyngsoe Systems, Wavecare, Icura, Corporate Health, Pressalit and UCL.

Her Royal Highness The Crown Princess of Denmark is patron of Healthcare DENMARK.

Visit www.healthcaredenmark.dk to learn more about some of the world’s best and most innovative healthcare providers and companies or to request meetings with the stakeholders who are future-proofing healthcare sectors around the world.



Stay updated with our newsletter
Visit our website healthcaredenmark.dk and sign up!

